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FERTILIZERS AND HUMUS*

The literature of the controversy centering on humus grows apace. A recent addition is at once a very readable and valuable, but a dangerous book.† The author is a chemist associated with the production of fertilizers, and consequently biassed, but that bias is freely admitted and, as far as is humanly possible, the arguments on both sides are presented with absolute fairness. It would be uncharitable, therefore, to stress examples where, in the eyes of one who has only a life's experience of practical agriculture in many countries and an aloof study of the controversy as presented by both sides to guide him, bias has entered into the presentation. If that life's experience has imparted a leaning to one party in the controversy, that must, again, be accepted as a bias.

The discussion opens with the case for fertilizers on the principle of cricket, that one side must bat first, and the massive volume of evidence that fertilizers lead to increased yield is reviewed. As presented, the account offers a strong plea for the combined use of fertilizers and humus. The case is carried further by a detailed consideration of the amounts of the plant-food elements available in the soil and of the amounts removed by crops. From this discussion, which indicates a marked adverse balance, it is argued that, if the demand for crop produce—particularly food—required by the human race is to be met, the high yields resulting from the use of fertilizers must be forthcoming. But that argument ignores one vital point; it assumes a world capacity for food production for ever meeting the requirements of an ever-expanding world population. Such an assumption may not be sound; man may become an epidemic in relation to the rest of Nature, and epidemics have a habit of self-extermination. It is the world capacity for food production which ultimately will determine the possible population and, if fertilizers prove incapable of sustaining a permanent high level of production, they can offer no permanent remedy.

Having exhausted the argument for fertilizers, the author proceeds to argue the case against with singular fairness in one who is admittedly biassed. He quotes from LARGE'S "The Advance of the Fungi" to show that epidemics in crop plants occurred when artificials were, if not unknown, at least not in sufficiently

* Article by D. H. M. Leake, reproduced from Int. Sug. Jr., 48, pp. 146–148.

† "Chemicals, Humus and the Soil" by Donald P. Hopkins. Faber and Faber, London. 1944.

general use to be a causative agent. Among the cases instanced is the potato epidemic of the hungry forties, since kept under control by sprays, which were used before the use of fertilizers became prevalent. Every plant becomes adapted to its natural environment, and is less at home as the distance from its focus and the divergence in the environmental conditions increase. It is arguable that the environmental divergences between its natural home in South America and Europe are such that the plant in the Old World is in an unbalanced state which renders it a ready prey. The argument has as little bearing on the conflict of fertilizers versus humus as the pro-humus arguments against which the author protests so strongly. After all, epidemics have been recorded from all time—they are mentioned in the Bible. They are liable to occur whenever the balance of nature is upset, and man's perceptions are too coarse to determine in every case the cause. Agriculture itself is an unnatural process, and crop plants and animals too, as the author recognises, are necessarily prone to disease to a greater extent than in a natural association of plants. To the onlooker the conflict must appear, in the words of OMAR, great argument about it and about.

The real problem surely is this : since disease may follow any conditions which react detrimentally on the health of the plant, do fertilizers tend to the production of such conditions ? To one whose personal experience includes failure to secure disease to enable varietal resistance to be tested, although present in epidemic form on exotic varieties included in the cultures and in the commercial growths surrounding them, there is justifiable evidence that it is in the conditions of growth that the causal difference lies. When, further, that experience covers at least one case of badly diseased plants losing all trace of, and remaining for years free from disease merely by ceasing fertilizer applications and reverting to compost dressings, he has at least presumptive evidence that fertilizers do produce conditions favouring disease. When, lastly, he has watched whole areas, during the war years, deteriorate to an extent which renders some normal cultural operations impossible, his disposition to attribute ill effects to the use of fertilizers must be pardoned, for the most obvious change in these years has been the increasing use of these. The evidence, it is true, is not conclusive ; accompanying changes have been the lesser use of humus and increased mechanization which may not only compact the soil but, by the rapid sequence of operations, allow too little time for effective aeration of the soil. One accompanying phenomenon is the increased tendency to form a hard pan, and there is here a field for investigation crying aloud ; how far is the hard pan the result of chemical or physical reaction ? It is not by argument, but by detailed study of such problems that the controversy can be settled. The problem as to whether it is possible or necessary for a permanent agriculture to eliminate fertilizers entirely may well be left for later enquiry, by a process of feeling the way towards the limits of their harmless use. It is, as has been somewhere said in this connexion, impossible to prove a negative. The disadvantage of an excessive claim is that it invites attack against the limiting position and the reasonableness of that attack is used to refute the moderate claim, as was recently indicated.

One further illustration may be given. A brief reference is made to the growing attention paid to trace elements as the cause of disease. If deficiency of these is a new fact and not merely the disclosure of recently gained knowledge, may not the explanation lie in the fact that humus may be the main natural source of these ? The living organisms from which humus is derived must have had their quota of these, collected at no expense to man from the traces in the soil, and it would seem uneconomic to replace this free service by an expensive industrial service. Again we do not know and will not know unless and until investigation replaces argument.

This leads to that aspect of the book which has been termed dangerous. Throughout, stress is laid on two points : first, that fertilizers are complements to manures, not substitutes ; second, that the supply of manures is entirely inadequate. The danger lies in the first of these, and its magnitude will vary in different countries. It is this : the view that fertilizers are complementary to manures is stated to be the orthodox view ; but can this be materially maintained ? In England, where the technical organization, including the research institutions, is woven into one vast monopoly, there is room for only one voice, and that voice is most certainly not that which the author terms orthodox. Not only has the use of fertilizers been forced on the farming community (it is wishful thinking to maintain that present use is the result of simple demand), but the sale of straw, that major source of humus on the farm, has been actively organised. No organised effort, for which the war offered so splendid an opportunity, has been made to turn the vast amounts of human wastes to agricultural purposes.

The second point has been, perhaps, sufficiently answered in the above, but it is accompanied by the question of cost. Again, has the official organization taken any steps to mechanize the muck heap ? It has remained for private enterprise to develop the muck shifter by which costs have been reduced from 12s. 6d. a ton to 1s. 8d. It may be true that materials for the manufacture of humus are in short supply, but that does not condone a calculated policy of diversion of those that are available. Certainly the complementary relation of fertilizers to humus is not the orthodox view where such action is possible.

One further point may be made. A whole section is devoted to the possible misuse of fertilizers with the claim that the evidence against is based on cases of such misuse. How far that is the case it would be difficult to say, but is not the compound fertilizer, issued as a standard for the particular crop with little attention to the nature of the soil on which the crop is to be grown, still the standard method of supply, and has any serious effort been made to organize

a soil testing service such as exists in Sweden, or to study methods of differential fertilization such as have been conducted by the Hawaiian sugar industry? The danger thus indicated lies in the fact that the reader, too little acquainted with the facts, will assume that the unexceptionable position taken up by the author, that fertilizers and humus are complementary, defines the policy adopted in practice. There is, no doubt, a growing realization of the possible misuse of fertilizers, but it is a comparatively novel outlook, as the soils of British Guiana bear witness, and has yet a long way to go before the author's position becomes worthy of the title orthodox. The danger indicated is particularly insistent in those countries in which there is a virtual monopoly of technical control. Where such control is less centralized, there is room for two voices, and the danger is less.

But the controversy has a deeper aspect. It illustrates the Tennysonian dictum that he that roars for liberty faster binds the tyrant's power and the tyrant's cruel glee forces on the freer hour. The immediate response obtained from fertilizers not unnaturally led to failure to appreciate the long-term effect and to an accepted belief in them which gradually became an accepted dogma. It is a human failing in those wedded to a dogma to resent criticism of that dogma and it is, perhaps, true that scientists are more prone than the common man to show such resentment since scientific belief is founded on reasoning from facts and criticism implies unsound reasoning or misreading of the facts. Criticism is met by denial, and denial, when issued by a monopoly (the Tennysonian tyranny), calls forth over-emphasis of the criticism. It is outside the scope of this review to discuss whether the humus school has, or has not, made excessive claims; that school has rendered a notable service in shaking the belief that the case for fertilizers is fool-proof. That school, too, can hardly be blamed, in view of the evidence that the author's view of the complementary nature of fertilizers and humus is not orthodox, if it regards the book as a screen behind which the fertilizer school, though not the author, will continue to wield its power, and if it seeks some more tangible expression of a change of opinion in the school as a whole. As a personal expression of opinion, the book is unexceptionable and will be, it is to be hoped, widely read; but it will be dangerous if the reader does not realize that it is not yet a representative or orthodox opinion that is expounded.

REVIEW

Forest Soils and Forest Growth

By S. A. WILDE, Pp. 241. Published by 'Chronica Botanica Company', Waltham, Mass. U.S.A. 1946, *Price: Five dollars* ($5.00)

The aim of the writer has been "to interpret forest soils as carriers of definite floristic associations, as plantations, and as dynamic systems that react to different forms of silvicultural cutting." It also stresses the importance of genetic soil groups as natural acclimatisation units. The book is divided into 20 chapters; the first four discuss the genesis of forest soils and describe the features of world soil groups. The next seven deal specifically with the ecological, physical, chemical and biological aspects of forest soils, forest humus, soil-forest types and forest soil surveys. The next five chapters discuss the selection of sites for tree planting, the amelioration of forest soils and various other aspects of silviculture and management, and the last four deal with the question of manuring forest soils, the maintenance of fertility and the control of parasites in nurseries. There are a number of diagrams, tables and charts, and seven plates. The treatment of the section descriptive of soils is based on the American point of view and the Thorp-Balwin classification of soils as outlined in *"Soils and Men"*, the U.S.D.A. 1938 Year Book, suitably modified to relate the principles to silviculture. Soils are regarded here as dynamic systems capable of producing timber; the forester's object is really to obtain the maximum quantity and quality of forest products from the soils under his charge, without damaging them or upsetting in any way their stability and productivity.

The particular sections of the book of interest to the student of soil science are undoubtedly those dealing with the relationships between genetical soil-types and types of forest which they support (Chapters III and IV and Table 2). The scarcity of relevant information on the relationship of tropical soils to tropical forest types and to forest ecology is stressed and an attempt is made to classify "lateritic" soils (soils of sesquioxide-enriched substrata) which is a valuable contribution to the subject although many authorities may not agree with the broad definition given at the outset of "laterite".

The printing is excellent and the diagrams and illustrations are well chosen and helpful. The book will undoubtedly be read by foresters who are interested in ecology and by soil scientists who are interested in natural forest soils.

F. H.

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A NEW METHOD OF ROOTING CUTTINGS OF HEVEA AND OTHER TREES

By
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Propagation of *Hevea* by cuttings has hitherto been successful only when the cuttings were taken from very young nursery plants or from the lower part of the stem of older seedlings. The first to report success was Bobilioff (2). Nursery plants showing only their first two leaves were ringed with fine wire, and after three weeks the stem above the wire was swollen. Cut at the rings and planted in a moist shady place the cuttings formed roots in another three weeks. Bobilioff also mentioned the earlier success of a Dutch nurseryman in Holland who rooted cuttings from young *Hevea* seedlings in a greenhouse without wiring. No growth substances were used in either of these experiments.

Baptist (1) used strong seedlings about two years old and cut the stem into pieces 15 inches long. The lower sections rooted to some extent (the lowest 19%, next 3%, third from base 3%) and when growth substance was used the percentages were greater (90%, 28% and 8% respectively). Leafless cuttings taken higher up the stem or from branches never produced any roots, even with growth substance. Their reserve materials became exhausted in the shade of the propagator and the cuttings died.

The work of Bobilioff and Baptist is of limited use for practical purposes. If clones are to be propagated on a commercial scale from cuttings, there must be some easy way of rooting terminal cuttings from shoots such as can be produced in quantity by bending down or cutting back budded nursery plants. Roelofsen (8) writing in 1939 on his successful experiments with coffee cuttings in a Trinidad type of propagator in Java, mentions that a great number of leafy top cuttings from strong nursery plants of *Hevea* were tried in the propagator, but after six months only six were still alive and only two of them later formed roots.

The I.C.T.A. propagator was designed in Trinidad for rooting cacao cuttings on a large scale, and Pyke (6) described the principles and technique. Similar propagators have since been built in Java, Puerto Rico and other countries (4, 5, 7, 8) and they have been found suitable for many tropical trees.

The main principle in this type of propagator is the reduction of transpiration to balance the limited uptake of water by the cuttings, and one important means to that end is the reduction of sunlight to about 8% of its full value (8). The reduction in solar radiation helps to keep the temperature in the bins below 30° C. as a rule; and in the middle of the day, when air temperature in the tropics sometimes rises to 33° or 34° C., a wet cheesecloth on the glass lids cools the bins by evaporation to about 30° C. The intensity of light in the bins corresponds to that below the trees in a full-grown *Hevea* plantation (8). More light cannot be given without raising the temperature to a point injurious to the cuttings. Intensity of light is therefore a limiting factor in this type of propagator, and whilst cuttings of shade-tolerant species continue to assimilate in the bins, the method is not so successful for light-demanding trees such as *Hevea,* mango, avocado or sapodilla.

Our first trials with *Hevea* were carried out in a modified form of I.C.T.A. propagator. The bins are 70 x 80 cm. with a free height above the sand of 35 cm. at the front of the bin. The permanent roof at 2 metres above the floor is a screen of bamboo laths 13 mm. wide with square interstices of 32 mm., which reduces the sunlight to a little more than 50%. Just below this permanent roof there are several very light frames covered with a double layer of cheeescloth. They are easily moved between V and T-balks, so that they can be quickly set aside when clouds are over the sun and put back when the sun shines again. The cheesecloth on the glass lids of the propagator is replaced by mosquito net, which not only lets through more light but also has a slightly greater cooling effect when wet.

Experiments showed that it was necessary to use two of the doubly covered cheesecloth frames to keep the temperature in the bins down to 30° C. Without any screen the temperature in the glass-covered bins rose to 48-53° C. and was lowered by the wet mosquito net to 41-47° C. With the bamboo screen in place the figures were 37-44° C. and 35-36° C. respectively. Only with the cheesecloth frames added could the temperature be held down to 30° C.

Attempts were made to compensate the low light intensity by addition of CO_2 to the air in the bins, and one to six litres of CO_2 per bin per day were administered in fractions every two hours through a hole in the front wall of the bin. The cuttings were tops of strong nursery plants 2-3 m. high, grown under very light shade, and had 22-24 leaves of which only about 12 were left on at setting, and six to nine cuttings were set in each bin. They remained in fairly good condition for two or three weeks, but after that showed progressive deterioration. Some leaves turned yellow, others were killed by fungi. When a few plants began to shed their leaves the experiment was discontinued.

Even those cuttings that still looked normal showed no trace of starch in the wood, though freshly cut material was full of it. No difference in this respect could be detected between the cuttings manured with CO_2 and those from control bins.

Latex was watery and scant. There seems no doubt that under these conditions the light is insufficient for assimiliation of carbon dioxide by *Hevea*, at least if the cuttings are from trees grown without shade or under light shade. Some method has therefore to be found by which the cuttings can be kept at a considerably higher light intensity than the I.C.T.A. propagator affords.

The only convenient way that suggested itself was to use a continuous spray of water over open bins. This would keep the leaves cool both by contact and by evaporation, would provide a permanently saturated atmosphere, and also allow a continuous supply of CO_2 by free ventilation. The question was whether the cuttings could endure a daily rain of 8 hours for weeks in succession.

In subsequent experiments the glass lids were left on the bins (with suitable screens) until 9.00 a.m. and replaced at 5.00 p.m. Between these hours the lids were taken off and the continuous spray used instead. Ideally the spraying should be done with a motor-driven sprayer producing a fine mist round the cuttings, but as this was not available the preliminary experiments had to be made with knapsack sprayers giving a coarser spray than was thought desirable. Nevertheless the *Hevea* cuttings did very well in the 8 hours daily rain with about 50% sunlight, and after some weeks looked even more healthy than at the beginning.

Six bins containing coarse river sand of granitic origin were planted with cuttings, on which about 12 leaves were left and the bigger ones cut back to one half. The treatments were as follows:

A. 2 bins (19 cuttings altogether) of terminal cuttings from strong 2-year-old seedlings.

B. 1 bin (12 cuttings) of similar cuttings manured daily with CO_2 (½ litre every hour from 8.00 a.m. to 1 p.m.).

C. 2 bins of cuttings from side branches of an old tree; one bin manured with CO_2 and one not.

D. 1 bin of subterminal cuttings from strong seedlings.

All the material was cut towards the end of the long dry season and was thus in a resting condition. The cut ends were washed for about an hour in water to remove the latex and then dipped for a few seconds in a 0.5 mgr./cc. alcoholic solution of indol-butyric acid. Four weeks later the treatment was repeated with 1.5 mgr./cc. indol-butyric acid.

After 6-8 weeks, 10 of the 19 cuttings in A had one or several roots, but of those in B only 2 rooted. In C no roots were formed, and in D only one cutting had roots. The terminal cuttings manured with CO_2 produced a much more abundant callus than the untreated ones, though fewer rooted; and there was likewise a more abundant callus on the cuttings from side branches manured with CO_2 than on the untreated controls.

In a second trial two of the six bins were set with cacao, one with 12 ordinary branch cuttings and one with 48 single-leaf cuttings with one inch of stem. Two-thirds of these cuttings were treated with a 2 mgr./cc. alcoholic solution of indol-butyric acid and one-third was left untreated. Of the 12 ordinary cuttings, 6 formed roots within 4 weeks, one of them an untreated cutting. The single-leaf cuttings were planted in various media—one row of 16 in coarse river sand, one row in a mixture of river sand and humus, one row in river sand. The best results were from the first row, in which 10 of the leaves had roots within 3 weeks, some of them rooting very freely.

Later trials showed that for cacao less light was desirable than for *Hevea*. When light was reduced by a suitable overhead screen to about 25%, with the spray used from 9.00 a.m. to 5.00 p.m., single-leaf cuttings from a young well-manured tree gave 95% rooting with indol-butyric acid treatment (2 mgr./cc. alcoholic solution) and 88% without it. Well rooted single-leaf cuttings hardened easily in half-closed bins. The axillary buds grew out within a month after planting in baskets, and took about four months to develop to a size suitable for planting in the field. This method is particularly useful when only small quantities of nursery material are available, which it is desired to multiply as quickly as possible. Vigorous, well-manured nursery stock is, however, essential for full success.

Branch cuttings of sapodilla (*Achras zapota* L.) root only with great difficulty, if at all. But cuttings from vigorous sucker growth gave 40% rooting without growth substance and 90% when treated with a 2 mgr. solution of indol-butyric acid. Watershoots of avocado (*Persea americana* Mill.) with similar treatment gave 60% rooting after 12 weeks.

These experiments will be continued on a bigger scale when new propagators and a power sprayer are available. The preliminary results show that by the spray method cuttings of various tropical trees can be kept in full health for months, and in many cases rooted, by exposure to much more light than is possible in closed bins. They are therefore published now in the hope of encouraging similar experiments in other tropical countries.

Summary

Cuttings of *Hevea* and some other light-demanding trees cannot be successfully rooted in the I.C.T.A. propagator on account of the low light intensity. By removing the lids in the day time and keeping the cuttings continuously sprayed with water, the light may be increased up to 50% of full sunlight with beneficial results. With 25% sunlight and the continuous daytime spray cacao can be propagated by single-leaf cuttings, which have some advantages over branch-cuttings.

In an experiment where CO_2 was added to the atmosphere round the cuttings there was increased callus formation but the number of cuttings rooting was less than in the controls.

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CONTROL OF CORDIA MACROSTACHYA IN MAURITIUS

Cordia macrostachya is a plant which was accidentally introduced into Mauritius from tropical America and has since spread rapidly over the island and become a serious weed. An account is given of the introduction of this weed into Mauritius and the part it plays in relation to local agriculture. An investigation of its insect fauna has been made in its native environment by entomologists at the Imperial College of Tropical Agriculture in Trinidad with a view to biological control of the weed in Mauritius by the introduction of its insect enemies.

The identity of the plant in the West Indies and Mauritius, its synonymy and nomenclature are discussed. The study of specimens at Kew Herbarium and field observations in the West Indies proved that the species in Mauritius is identical with that in Trinidad. The position occupied by the weed in the secondary vegetation of Mauritius is explained, and contrasted with that which it occupies in Trinidad, Barbados and Saint Lucia. In Mauritius it has considerable invading power and is a dominant constituent of lowland scrubs, while in the West Indies it is a subordinate species in secondary vegetation.

Data on the reproduction, dispersal and germination of the weed in Mauritius are presented and discussed. It is shown that one acre of land invaded by the plant produces yearly 133,920,000 fruits which are readily dispersed by birds. The flower : fruit ratio was found to be 1 : 0.28 in Mauritius and 1 : 0.03 in Trinidad, while the germination of the seeds varies from 76 per cent. to 88 per cent. in Mauritius and from 18 per cent. to 85 per cent. in Trinidad.

Evidence is put forward of the correlation in Trinidad between insect damage to the reproductive parts and the low production of fruits. It is concluded that the aggressive power displayed by the weed in Mauritius can partly be attributed to the fact that reproduction proceeds unchecked, while in Trinidad the invading power of the plant is reduced because of widespread insect damage to the flowers and fruits. The work carried out on the insect fauna of the weed at the Imperial College of Tropical Agriculture is reviewed. Eighty species of insects have been recorded so far excluding casual visitors. Those which appear to offer greater possibilities from the point of view of biological control are listed. The possible introduction into Mauritius of two beetles attacking the foliage is discussed. It is concluded that further work on these insects in Trinidad is desirable before they are introduced into Mauritius.

The future of researches on this problem in Trinidad is outlined. These investigations will be carried out henceforth under the auspices of the Imperial Bureau of Biological Control working in collaboration with the Imperial College of Tropical Agriculture. An entomologist has already been appointed to undertake these studies. Suggestions as to the more profitable lines of research are indicated. It is considered important that special attention should be devoted to the insects attacking the flowers and fruits of the plant in Trinidad with a view to their introduction into Mauritius. Although the basic line of approach to the control of this weed in Mauritius must rest with biological methods, there are possibilities that certain plant growth substances used as herbicides may help to control the weed in special cases. The control of weeds by this means is further discussed.

(Adapted from "Report on a visit to Trinidad, Louisiana and other countries" by P. O. Wiehe, Mauritius Government Publ. 28, 1946.)

GRASSWORM INJURY TO LAWNS IN PUERTO RICO

By
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In warm climates the larvae of several species of moths may be present in both wild and cultivated grasses at one time or another throughout the year. Under certain conditions they may become so abundant as to cause considerable damage. Usually, however, these insects go unnoticed until most of their damage has already been done and they have reached such a stage of development that the application of insecticides is of no beneficial effect. Leaf skeletonization, often seen in the late summer and fall, is evidence of the presence of newly hatched larvae of one of the commonest of these insects, the fall armyworm (*Laphygma frugiperda* (A. & S.)). Injury to lawn grasses by this and two other insects, not usually so common, was observed at the Federal Experiment Station at Mayaguez during the summer of 1946.

Beginning about the middle of June grassworms were observed in several sections of the station lawns where gramma (*Paspalum conjugatum* Berg.) was the predominating grass. By the end of the month sod in these areas was completely defoliated, and in places where other kinds of grass were growing, heavy feeding was evident. The damage was due in part to the fall armyworm, but most of it was caused by slim greenish larvae about ½ inch long that lightly webbed together the lower leaves of the grass. The small brown moths produced by these larvae were identified as *Pachyzancla* (formerly *Psara*) *phaeopteralis* (Guen.)[1]. Both species of insects have been known for a long time to attack grasses more or less severely, [2] but recovery has usually been rapid without the use of insecticides. [3]

In most of the areas under observation there appeared to be four times as many *Pachyzancla* larvae present as of *Laphygma* and about half of each were full-grown and preparing to pupate. Two weeks later, i.e. about the middle of July, this ratio was reversed and many *Pachyzancla* moths were observed on the wing in situations protected from the wind in the late afternoon. At about the same time, dirty-whitish larvae of approximately the same size as those of *Pachyzancla* began to appear in densely sodded areas. These larvae confined most of their feeding to the base of the grass stalks next to the ground, where they constructed loosely-woven shelters of bits of grass and frass. These shelters were later formed into spindle-shaped cocoons extending vertically above the litter that usually accumulates in such situations. The slim golden-brown moths about 1/3 inch in length reared from the larvae were identified as *Crambus legonellus* Zell. [4] This insect was described many years ago from Puerto Rico as *C. detomatellus Moschler*.[2] This is the first definite record, so far as known to the writer, of the feeding of this species on grasses in Puerto Rico.

Areas containing a mixture of grasses exhibited important differences in susceptibility to these three insects. Gramma and Java grass (*Polytrias praemorsa* (Nees) Hack.) were generally completely defoliated by *Laphygma* and *Pachyzancla*, while the sedge, nutgrass or "coqui" (*Cyperus rotundus* L.) and centipede grass (*Eremochloa ophiruoides* (Munro) Hack.) were apparently not attacked. Bermuda grass (*Cynodon dactylon* (L.) Pers.) was only moderately attacked by all three but principally by *Laphygma*. In some cases where Bermuda grass was growing under adverse conditions some areas a few feet in diameter harboured two or three larvae per square foot. These areas were characterized by extensive leaf skeletonization, some wilting, and finally some browning of the tops. However, the root stalks appeared to be little affected and, except for the appearance of a few weeds which were not fed upon by the larvae, these areas in 2 months were well on their way to recovery.

Manila grass (*Zoysia matrella* (L.) Merr.), which has been gaining in popularity as a lawn grass, particularly in the southern United States, and which has been singularly free from insect attack, showed relatively little evidence of leaf feeding by *Laphygma*. However, *Pachyzancla* larvae and later those of *Crambus* were abundant in small scattered areas of nearly pure stands of this grass totalling about 2 acres. Feeding seemed to be confined to the middle and lower parts of the stems, which caused the tops to wither or die and brown spots to develop here and there in the lawn. In addition, the lawn as a whole appeared to be thinned somewhat by general feeding. As with Bermuda, the root stalks seemed to be little affected and by the latter part of August, with the resumption of the seasonable rains, all the larvae disappeared, the wilted spots began to turn green again, and the small brown areas began to close in. By the end of September, the wilted spots had entirely disappeared as had all but a few of the largest brown areas. To facilitate the closing of these

[1] Verified by Carl Heinrich, Bureau of Entomology and Plant Quarantine, Washington, D. C.

[2] Wolcott, Geo. N. "Insectae borinquenses," a revised annotated check-list of the insects of Puerto Rico. With a host-plant index by Jose I. Otero. *Puerto Rico Univ. Jour. Agri.* 20 : 1-627 illus. 1936. (See pp. 423, 465.)

[3] Wolcott, Geo. N. An economic entomology of the West Indies. 688 pp., illus. 1933. (See p. 262.)

[4] Determined by Carl Heinrich, Bureau of Entomology and Plant Quarantine, Washington, D. C.

latter and discourage the entrance of weeds, such as nutgrass, it was necessary to replant with 2-inch blocks of Manila grass sod.

Recovery in all cases was no doubt promoted by the presence of natural enemies of the grassworms. Small flocks of the black Puerto Rican grackle, or "mozambique" (*Holoquiscalus niger brachyopterus* (Cassin)), always present on the station grounds, were frequently observed foraging over the infested areas. While their effective reduction of the insect population most likely was confined to areas of thin-sodded grasses, such as Java, these birds were also seen feeding on larvae in deep-sodded Manila grass. During the latter part of July when infestation by all three species of insects was at its height, numerous *Laphygma* larvae were seen attacked by a disease which doubtless aided considerably in control. In the deep sod the small white cocoons of an unidentified braconid parasitic wasp were found near *Laphygma* larvae, and the chalcid wasp, *Spilochalcis femorata* (F.), [5] was reared from the *Crambus* larvae. It is probable that these and other natural enemies not observed caused the gradual disappearance of all three species of grassworms.

[5] Determined by A. B. Gahan, Bureau of Entomology and Plant Quarantine, Washington, D.C.

Summary

In the summer of 1946 larvae of the moths, *Laphygma frugiperda* (A. & S.), *Pachyzancla phaeopteralis* (Guen.), and *Crambus legonellus* Zell., extensively defoliated the lawn grasses, *Paspalum conjugatum* Berg. (gramma) and *Polytrias praemorsa* (Nees) Hack. (Java grass). They only moderately attacked *Cynodon dactylon* (L.) Pers. (Bermuda grass) and seemed to avoid *Eremochloa ophiuroides* (Munro) Hack. (centipede grass) and the sedge, *Cyperus rotundus* L. (nutgrass or "coqui"). Feeding on *Zoysia matrella* (L.) Merr. (Manila grass) was moderate, but, as with the other grasses following seasonable rains, recovery without the use of insecticides was well under way in 2 or 3 months after infestation was noticeable. Birds, a disease, and internal parasites attacked the larvae in heavily infested areas.

WAR ON WEEDS

Herbicides are divided into the following groups :—

(1) Soil sterilants such as sodium arsenite, ammonium thiocyanate, borax or borate ores, carbon bisulphide, chloropicrin and sodium chloride. For killing deep-rooted perennials, 250 lb. of sodium chloride + 15-30 lb. of borax + 3-4 lb. of sodium arsenate per square rod are required.

(2) Non-selective contact sprays such as oil, acid and salt derivatives that kill all vegetation above ground. Many contain sodium arsenite alone or combined with sodium chlorate. This is poisonous to livestock and is a fire hazard.

Newer herbicides include (3) selective sprays like sulphuric acid, oils and Sinox which wilt most broad-leaved weeds but leave grains, flax and grasses unaffected. One gallon of sulphuric acid in 50 gallons of water sprays half an acre and kills most weeds rapidly. Sinox, a coal-tar derivative, is used as a spray from aeroplanes. One gallon of Sinox in 120 gallons of water applied at the rate of 80-100 gallons per acre killed only broad-leaved annuals and had little effect on grasses. Flax and peas should not be sprayed with it before reaching 3 inches height and never after bud formation. Alfalfa and red clover developed high resistance to it when 4-6 weeks old. Light-weight oils applied full strength are used for weeding carrots when the crop is less than three inches tall. Members of *Umbelliferae* are tolerant to oil sprays.

(4) Poisons like arsenic trioxide, arsenic trichloride, sodium chlorate, ammonium sulphamate. ¾ lb. of ammonium sulphamate in a gallon of water applied at the rate of 1-3 gallons per 100 square feet is more suitable than sodium chlorate. It does not leave the soil sterile for more than a short time and it contains fixed nitrogen which enriches the soil.

(5) The Sizz-weeder produces a hot-air-blast which is applied when the cultivated crop has a greater fibre content than the weeds. It destroys the weeds and leaves the crop unharmed.

(6) Hormones such as those known as 2, 4—D and 2, 4, 5—T stimulate abnormal growth which kills the plants. Small doses such as ¼ to ½ oz. per square yard are effective. They may be applied in water sprays or incorporated into dust or aerosols. They attack most broad-leaved plants and are most effective on young plants. Plants are killed after about one month. Hormone application should be made within four hours of rain; it is most effective on plants growing in moist soil and is more rapid in sun than in shade.

(7) Machines for moving and crushing plants, and soil covers to suffocate weed growth. (*Soils and Fertilizers*, 9, 212, 1946.)

The Editor is prepared to consider signed articles for publication in *Tropical Agriculture*. Such articles should normally vary between 1,000 to 6,000 words and may be illustrated if desired.

EFFECTS OF INCREASING PHOSPHATE DOSAGES ON THE UTILISATION OF NITROGEN

Preliminary Results of Pot-Tests on Sugar-Cane Soils

BY

F. HARDY

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(I) Introduction

The determination of approximate nutrient requirements by the Mitscherlich pot-test in samples representative of important soil-types occurring in the British West Indies has shown a widespread deficiency of available phosphate. Among the soil-types so far examined by the Mitscherlich method, two sugar-cane soils occurring in Trinidad are outstanding in their remarkable response to superphosphate manure; namely :—

(1) *Princes Town Heavy Clay* :* This is a black Rendzina soil overlying highly calcareous marlstone. It is widespread in the Naparima District of South Trinidad and comprises the best sugar-cane soil of the Ste. Madeleine sugar estates. Similar sugar-cane soils occur in Antigua† and Barbados.

(2) *Talparo (Red) Clay* :‡ This is a red, ferruginous, highly acid soil overlying non-calcareous grey siltstone usually rich in gypsum. It is also widespread in the south of Trinidad where it comprises a sugar-cane soil of low productivity, prevalent in the Ste. Madeleine sugar estates. It is also common in the Northern Plain of Trinidad where it mostly occupies peasants' holdings where not in forest or bush.

In addition, a third soil-type, likely to be increasingly used for sugar-cane growing in the future, was examined by the standard Mitscherlich method, namely :—

(3) *Sangre Grande Silty-Clay* :§ This is a yellow alluvial soil prevalent over river flats in the Northern Plain of Trinidad. It mostly comprises marginal cacao land but in recent years has largely been utilised for growing ground provisions in peasants' "war gardens". In some areas it represents an important peasants' sugar-cane soil.

Another interesting soil-type, also examined by the Mitscherlich method, though not a Trinidadian soil, is :—

(4) *St. Vincent Recent Volcanic Ash* :* This is an immature sandy soil (lithosol) occurring over the lower slopes of Soufriere in the north of the island of St. Vincent. It consists of almost unaltered fine ejecta from the 1902-3 eruptions. It comprises the chief soil of Mount Bentinck Estate which is the largest sugar estate in the Island.

Representative samples of these four soil-types gave the results set out in Table I when they were examined at different times by the Mitscherlich pot-test. The sample of Princes Town Heavy Clay was taken from a hill-crest where the calcareous soil parent material was exposed through severe erosion, so that it is actually a subsoil. The next two were topsoil samples taken at depths of 0-10 inches and 0-8 inches respectively. The last sample was taken at 4 ft. depth from the bank of the Rabaka Dry River near Mt. Bentinck, St. Vincent. It also is a subsoil.

The "phosphate requirement for maximum yield" of each of the three soils, according to Mitscherlich's standards, is apparently very high, ranging from 7 to 10 cwt. per acre of superphosphate manure. This is a much higher dosage than would ordinarily be applied in sugar-estate practice where quantities greater than 2 or 3 cwt. acre of superphosphate are seldom prescribed. It should be noted, however, that the rates of application of nitrogenous, phosphatic and potassic manures employed as the regular Mitscherlich treatments are relatively very high, namely, 12½ cwt. acre of ammonium sulphate, 16 cwt. acre of superphosphate and 7½ cwt. acre of potassium sulphate, that is, in the proportion of about 5 to 6 to 3. While these amounts are very much greater than the customary agricultural quantities used in sugar-cane growing, yet dosages of ammonium sulphate and of potassium sulphate equal to half the Mitscherlich dressings or more, are not infrequently employed, whereas a dosage of 8 cwt. acre of superphosphate would be considered as unnecessarily high. Since many sugar-cane soils in the British West Indies have been found to be very deficient in available phosphate, it is difficult to understand on these grounds why phosphatic manures have not been used more frequently and in greater quantity, especially when the cost per ton in comparison with that of the other two kinds of manure is relatively low under normal

* Assessment of Fertility of Abnormal Soils: (A) Rendzina or Humus-Carbonate Soil. F. Hardy and A. S. Harper, *Trop. Agric. Trin.*, 1941, XVIII, Pp. 214-221.

† The Phosphate Requirement of Calcareous Soil (Antigua), F. Hardy, D. M. Hanschell and E. H. Amoroso-Centeno, *ibid.*, 1938, XV, Pp. 183-186.

‡ Assessment of Fertility of Abnormal Soils: (B) Ferruginous Red Soils. F. Hardy, A. S. Harper and E. G. Cripps, *ibid.*, 1941, XVIII, Pp. 238-243.

§ Soil Fertility of Some Peasants' Lands in Trinidad, F. Hardy and A. S. Jordan, *ibid.*, 1946, XXIII, Pp. 12-19.

* Subsoil Fertility of Eroded Volcanic Ash in St. Vincent, B.W.I. F. Hardy and E. G. Cripps, *ibid.*, 1944, XXI, Pp. 30-39.

market conditions. Perhaps the explanation lies in the fact that the arbitrary magnitudes of the dressings of phosphatic manures that are included in conventional field experiments now in vogue in the British West Indies are too low to have produced any outstanding responses.

There is evidently a need for further experimental work designed to examine the complex phosphate relationships of our sugar-cane soils. In the investigations to be described below, two main aspects of the problem have been considered, namely :—(1) the effects of increasing arbitrary dosages of phosphatic manure, in the presence of initial high dosages of nitrogenous and potassic manures, on the yield of Sudan Grass in pot-cultures of phosphate-deficient soils, and (2) the modifying influence of phosphate fixation on the response of the indicator plant to the varying manurial treatments. Unfortunately, through lack of greenhouse space and the necessary equipment, only the simplest design of experiment could be employed, so that these investigations should be regarded only as preliminary to further detailed studies.

(II) Response to increasing Dosages of Phosphate

Soils : The pot experiments with increasing dosages of phosphate manure were conducted with the following six soils :

(A) Princes Town Heavy Clay (subsoil)—Petit Morne, Ste. Madeleine.
(B) Talparo (Red) Clay—Ben Lomond, Ste. Madeleine.
(C) St. Vincent Volcanic ash (subsoil)—Soufriere, St. Vincent.
(D) Sangre Grande Silty-Clay—St. Helena, North Trinidad.
(E) Maracas Sand (detrital phase)—I.C.T.A. College Farm.
(F) Cunupia Clay.—Frederick Section, Caroni Estate.

The first three soils were the same as those described in the last section, and were taken from the same stock as that which provided the material for the previous standard Mitscherlich or other pot-tests. The fourth was collected at St. Helena Estate and has

TABLE I.—PHOSPHATE STATUS OF SUGAR-CANE SOILS AS DETERMINED BY THE MITSCHERLICH POT-TEST

Soil-type	Determined by chemical analysis				Determined by Mitscherlich pot-test				Ratio
	Index of Texture	Re-action (pH)	Org. matt. (%)	Avail. P_2O_5 p.p.m.	Avail. P_2O_5 p.p.m.	Avail. P_2O_5	Diff. from optimum hundredwt per acre	Equiv. super-phosphate	Chem./ Mitsch.
P.T. Heavy Clay (subsoil) ...	39	7.5	1.6	11	9	0.16	1.59	8.8	1.22
Talparo (Red) Clay (topsoil)	32	4.6	1.5	12	0.3	0.01	1.74	9.6	(40)
S.G. Silty-Clay (topsoil) ...	37	4.6	3.2	32	21	0.61	1.14	6.3	1.52
St. Vincent Volc. Ash (subsoil)	3	5.9	0.3	84	0.1	0.002	1.748	9.7	(840)

TABLE II.—LABORATORY DATA FOR THE SOILS EXAMINED

	Silt and clay %	Moisture at sticky point %	Index of texture	Reaction Normal pH	Reaction Ex-change pH	Total org. matt. %	Total nitrogen %	Carbon nitrogen Ratio	Avail. phos-phate† p.p.m.	Avail. potash ‡ p.p.m.
(A) P.T. Heavy Clay ...	85	50.7	84	7.6*	7.1	1.78	.153	6.7	**12**	**188**
(B) Talparo (Red) Clay ...	90	41.3	39	4.8	3.8	2.10	.172	7.1	**13**	**146**
(C) St. Vincent Volc. Ash ...	28	23.4	9	6.1	5.5	0.84	.141	11.9	**63**	**188**
(D) S.G. Silty-Clay ...	75	38.4	33	6.3	5.0	2.79	.211	7.7	**12**	**88**
(E) Maracas Sand ...	47	23.6	13	5.3	4.9	2.57	.106	14.1	**8**	**39**
(F) Cunupia Clay ...	84	36.0	33	6.8	6.5	2.28	.187	7.1	84	**142**

*containing 8.4 per cent. of free calcium carbonate.
† Truog's method : Limits of adequacy ; clays 35, sands 25 ppm.
‡ Exchangeable K_2O : Limits of adequacy ; clays 180, sands 120.
Deficiencies are denoted by bold face figures.

been employed for growing peasants' sugar-cane for the past 14 years. The fifth sample is a typical College Farm sugar-cane soil taken from the writer's garden which was once a peasants' holding; it is known as *Maracas Sand* (*detrital phase*). The last soil is a sugar-cane soil from Field 88, Frederick Section of Caroni Estate, named *Cunupia Clay;* it was taken from the "bad" plot of our early investigations on the froghopper pest. The last two samples, (E) and (F), represent top foot layers. Laboratory data for all these six soils are given in Table II.

Phosphate status: Soil samples (A), (B), (D) and (E) are evidently very deficient in available phosphate. Soil (C), St. Vincent Volcanic Ash, though giving a high Truog value for available phosphate, was found by previous pot-tests to have a very high phosphate requirement.*

Potash status: Each of the six soils is somewhat deficient in available potash but all except two, (D) and (E), are near the border line of adequacy. The Mitscherlich test applied to the soils (A) and (B) showed very low potash requirements which could be satisfied by 0.4 and 0.8 cwt. acre of potassium sulphate respectively. Soil (C) showed no potash requirement at all; Soil (D), however, would require 2.3 cwt. acre of this manure for maximum production. The potash requirements of Soils (F) and (E) have not been determined.

Lime Status: The soils differ in reaction (pH value), indicating different lime requirements for neutrality. These were determined on the acid representatives by the Hardy-Lewis titration method† for pH 7.2.

The following results were obtained :—

Soil	(B)	(C)	(D)	(E)	(F)
Lime requirement (tons/ac. 4½ ins.)	4.31	0.28	1.93	0.01	0.74

Only the heavy acid soils, (B), (D) and (F), were considered likely to benefit from liming. They were accordingly tested by the pot method after liming, as well as without lime.

The necessary amounts of powdered 100-mesh limestone were intimately mixed with the dry soils before potting.

Experimental procedure :‡ The six unlimed soils and the three limed soils were introduced with the usual precautions into standard Mitscherlich pots, ten pots full for each soil. Each pot holds about 6¾ lb. of air-dry soil when filled to 4½ ins. depth, with gravel below as drainage. The following manurial treatments were then given by adding the calculated amounts of standard manures in solution, viz. ammonium sulphate, potassium sulphate and superphosphate. The first two pots in each series received no artificial manures at all, the others each received a basal dressing equivalent to eight (8) cwt. acre of ammonium sulphate and two (2) cwt. acre of potassium sulphate. Pot 3 received, in addition, the equivalent of one (1) cwt. acre of superphosphate; Pot 4 two (2) cwt. ac.; Pot 5 four (4) cwt. ac.; Pot 6 six (6) cwt. ac.; Pot 7 nine (9) cwt. ac.; Pot 8 twelve (12) cwt. ac.; Pot 9 eighteen (18) cwt. ac.; and Pot 10 twenty-eight (28) cwt. per acre.

When the manures had been added to the soils in the pots, after allowing them to take up water by partial immersion, the cultures were set aside for a fortnight to allow the soil and the added manure to come to equilibrium. The soil surface was then scarified, remoistened, and sown with Sudan Grass (*Andropogon sorghum* var. *sudanense*) in the manner employed in the standard Mitscherlich test. Watering was started after the seeds had germinated. Later the seedlings were thinned out to 35, as customary. Watering was subsequently carried out twice a day, the drainings being returned to their respective pots. The crops were reaped after 12 weeks' growth by which time practically all the plants were flowering. *Results* : The number of plants (stems) in each culture was counted and also the number of tillers per plant. Root matter, as well as stems and tillers, after separating from the soil by wet-sieving, were dried and weighed. The results obtained are presented in Table III.

(III) Phosphate Fixation

Experimental procedure : In order to measure the comparative capacity which the different soils possess for fixing added phosphate, the following arbitrary procedure was applied :—

A solution was made up of pure sodium hydrogen phosphat ($Na\ H_2\ PO_4.\ H_2O$ containing 1.051 g. of salt, or 0.64 g. P_2O_5 per litre. Appropriate volumes of this solution were added to 50 g. portions of air-dry soil to correspond with the different dosages of superphosphate manure used in the pot tests. (A dressing of one hundredweight per acre of this manure is equivalent to 1.75 cc. of solution per 50 g. of soil. Enough water was added to bring the volume up to 50 cc. and the liquid then added to the soil to make a thin paste, which, after stirring in a beaker, was slowly dried down on a water-bath. The dry soil was powdered and well mixed. Two gram portions were then agitated, each with 400 cc. distilled water in an end-over-end shaker for 30 minutes. Phosphate was determined in the extract, as well as in the soil after filtration and washing, using the Truog method.

* This soil-type usually behaves abnormally in this respect; on extraction with the Truog reagent (a 0.01 per cent. solution of sulphuric acid), the first filtrate gives a relatively high value for phosphate content, whereas subsequent filtrates, obtained by repeated extraction with the reagent, give low and diminishing values. When tested by the standard Mitscherlich pot-test and by the tomato-seedling pot-test, Volcanic Ash Lithosol generally shows no phosphate shortage.

† *Journ. Agric. Sci.*, 1929, XIX, p. 17.

‡ The pot-tests were carried out by C. Baboolal, Technical Assistant.

TABLE III.—RESULTS OF POT-TESTS

(Sudan Grass as indicator plant)

Culture	Treatment	Total No. of plants reaped	No. of tillers	Mean No. of tillers per plant	Oven-dry weight of crop: Stems (g)	Tillers (g)	Roots (g)	Total dry matter (g)	Ratios (weights): Stems/Tillers	Stems+Tillers/Roots
Princes Town Heavy Clay : Marly subsoil (Ste. Madeleine)										
A. 1	Nil	32	32	1.0	10.5	0.3	4.5	15.3	35.0	2.2
2	Nil	32	17	0.6	11.8	0.7	4.0	16.5	16.9	2.5
3	NK *plus* P	22	53	2.4	18.5	5.5	9.5	33.5	3.4	1.2
4	,, 2P	24	48	2.0	20.0	4.0	7.5	31.5	5.0	3.2
5	,, 4P	18	58	3.2	28.0	11.0	9.5	48.5	2.5	4.1
6	,, 6P	19	59	3.1	23.8	16.0	10.0	49.8	2.4	4.0
7	,, 9P	29	51	1.8	42.8	15.0	17.5	75.3	2.8	3.3
8	,, 12P	23	55	2.4	49.0	8.0	22.0	79.0	6.1	2.5
9	,, 18P	25	50	2.0	44.5	12.1	16.5	73.1	3.7	3.4
10	,, 28P	26	46	1.8	53.3	12.5	18.5	84.3	4.3	3.6
Talparo (Red) Clay : topsoil (Ste. Madeleine)										
B. 1	Nil	16	0	0.0	0.2	0.0	0.1	0.3	—	2.0
2	Nil	12	0	0.0	0.3	0.0	0.2	0.5	—	1.5
3	NK *plus* P	15	0	0.0	0.2	0.0	0.3	0.5	—	0.7
4	,, 2P	14	0	0.0	0.3	0.0	0.5	0.8	—	0.6
5	,, 4P	7	0	0.0	0.7	0.2	0.5	1.4	3.5	1.8
6	,, 6P	9	14	1.6	1.3	0.7	1.0	3.0	1.9	3.0
7	,, 9P	15	36	2.4	7.0	1.8	3.0	11.8	4.0	2.9
8	,, 12P	19	52	2.7	13.0	3.3	7.0	23.3	4.0	2.3
9	,, 18P	13	40	3.1	15.0	6.0	6.5	27.5	2.5	3.2
10	,, 28P	14	74	5.3	17.3	8.3	7.0	32.6	2.1	3.6
Ditto : Limed										
B L 1	Nil	18	16	0.9	4.3	0.3	2.5	7.1	14.3	1.8
2	Nil	28	0	—	2.3	0.5	1.5	4.3	4.6	1.8
3	NK *plus* P	22	11	0.5	9.5	0.7	5.0	15.2	13.6	2.0
4	,, 2P	22	35	1.6	23.8	1.8	9.0	34.6	13.2	2.6
5	,, 4P	16	42	2.6	24.3	8.0	9.0	41.3	3.0	3.6
6	,, 6P	19	56	3.0	23.3	14.3	10.5	48.1	1.6	3.6
7	,, 9P	19	28	1.5	51.8	9.3	21.0	82.1	5.6	6.6
8	,, 12P	18	45	2.5	46.0	12.3	18.0	76.3	3.7	3.3
9	,, 18P	18	30	1.7	41.3	15.5	12.5	69.3	2.7	4.5
10	,, 28P	23	52	2.3	45.5	15.3	22.0	82.8	3.0	2.8
St. Vincent Volcanic Ash : Subsoil (Soufriere)										
C. 1	Nil	29	16	0.5	1.7	0.1	2.0	3.8	17.0	9.0
2	NK *plus* P	28	18	0.6	12.3	1.0	3.0	16.3	12.3	4.4
3	,, 2P	26	27	1.0	41.0	5.0	12.5	58.5	8.2	3.7
4	,, 4P	20	33	1.6	54.0	7.5	17.5	79.0	7.2	4.1
Sangre Grande Silty-Clay : topsoil (St. Helena, Trinidad)										
D. 1	Nil	17	34	2.0	14.5	6.0	8.0	28.5	2.4	2.6
2	Nil	13	35	2.7	15.0	6.3	7.5	28.8	2.4	2.8
3	NK *plus* P	17	40	2.4	33.0	7.0	13.0	53.0	4.7	3.1
4	,, 2P	17	34	2.0	38.0	7.0	14.5	59.5	5.4	3.1
5	,, 4P	18	39	2.2	33.3	7.7	14.5	55.5	4.3	2.8
6	,, 6P	21	54	2.6	39.7	7.0	15.0	61.7	5.7	3.1
7	,, 9P	20	52	2.6	38.3	14.0	16.5	68.8	2.7	3.2
8	,, 12P	17	45	2.7	33.2	15.2	20.5	68.9	2.2	2.4
9	,, 18P	16	45	2.8	36.3	9.3	15.0	60.6	3.9	3.0
10	,, 28P	15	62	4.1	44.0	13.7	20.5	78.2	3.2	2.6

TABLE III.—RESULTS OF POT-TESTS—*Continued*

(Sudan Grass as indicator plant)

Culture	Treatment	Total No. of plants reaped	No. of tillers	Mean No. of tillers per plant	Oven-dry weight of crop: Stems (g)	Tillers (g)	Roots (g)	Total dry matter (g)	Ratios (weights): Stems/Tillers	Stems+Tillers/Roots
	Ditto : Limed									
DL 1	Nil	20	60	3.0	9.3	5.3	8.0	22.6	1.8	1.8
2	Nil	22	38	1.7	15.5	4.5	8.0	28.0	3.5	2.5
3	NK *plus* P	20	60	3.0	11.7	5.5	5.5	22.7	2.1	3.1
4	,, 2P	18	84	4.7	14.3	9.3	7.0	30.6	1.5	3.4
5	,, 4P	20	53	2.6	31.7	15.0	17.0	63.7	2.1	2.8
6	,, 6P	21	57	2.7	26.7	5.5	12.0	44.2	4.8	2.7
7	,, 9P	17	63	3.7	27.0	12.0	13.5	52.5	2.2	2.9
8	,, 12P	17	73	4.3	23.7	9.0	12.5	45.2	2.6	2.6
9	,, 18P	18	72	4.0	27.0	12.8	13.5	53.3	2.1	3.0
10	,, 28P	21	54	2.6	40.5	13.7	20.0	74.2	3.0	2.7
	Maracas Sand : (Detrital Phase) topsoil, I.C.T.A. Garden									
E. 1	Nil	20	0	—	1.1	—	0.1	1.2	—	11.0
2	Nil	25	0	—	1.1	—	0.2	1.3	—	5.5
3	NK *plus* P	28	9	0.3	15.0	0.3	3.1	18.4	50.0	4.9
4	,, 2P	29	15	0.5	24.7	1.0	7.0	32.7	24.7	3.7
5	,, 4P	22	26	1.2	33.0	7.0	10.4	50.4	4.7	3.8
6	,, 6P	21	32	1.5	32.8	6.5	10.5	49.8	5.0	3.7
7	,, 9P	18	22	1.2	32.5	7.0	12.0	51.5	4.6	3.3
8	,, 12P	19	22	1.2	39.0	4.3	13.2	56.5	9.1	3.3
9	,, 18P	18	26	1.4	35.0	10.0	13.5	58.5	3.5	3.3
10	,, 28P	18	24	1.3	21.5	11.0	9.2	41.7	1.9	3.5
	Cunupia Clay : topsoil ("Bad" Plot : Frederick 88, Caroni)									
F. 1	Nil	20	45	2.2	26.3	6.3	9.5	42.1	4.2	3.4
2	Nil	18	33	1.8	33.8	5.0	9.0	47.8	6.8	4.3
3	NK *plus* P	21	60	2.9	32.8	10.3	11.5	54.6	3.2	3.8
4	,, 2P	18	57	3.2	15.3	11.3	13.5	40.1	1.4	1.9
5	,, 4P	14	92	6.6	40.3	16.8	12.0	69.1	2.4	4.8
6	,, 6P	17	73	4.3	41.3	15.3	15.0	71.6	2.7	3.8
7	,, 9P	19	82	4.3	34.0	14.3	16.0	64.3	2.4	3.0
8	,, 12P	19	85	4.4	39.0	20.8	15.0	74.8	1.9	4.0
9	,, 18P	20	109	5.4	48.7	23.0	18.5	90.2	2.1	3.9
10	,, 28P	14	75	5.3	46.7	20.3	20.5	87.5	2.3	3.2
	Ditto : Limed									
FL 1	Nil	24	47	1.9	36.3	5.3	12.0	53.6	6.9	3.5
2	Nil	26	24	0.9	44.7	2.0	14.0	60.7	22.3	3.3
3	NK *plus* P	27	64	2.4	45.7	9.0	17.5	72.2	5.1	3.1
4	,, 2P	18	80	4.4	30.8	5.3	9.5	45.6	5.8	3.8
4	,, 4P	16	37	2.3	36.3	16.8	14.0	67.1	2.2	3.8
6	,, 6P	19	62	3.3	37.8	9.8	15.0	62.6	3.8	3.2
7	,, 9P	18	43	2.4	25.3	7.8	9.5	42.6	3.2	3.5
8	,, 12P	17	47	2.8	31.3	6.8	10.0	48.1	4.6	3.8
9	,, 18P	13	58	4.5	40.8	14.3	12.5	67.6	2.8	4.4
10	,, 28P	17	51	3.0	30.3	10.3	10.0	50.6	2.9	4.1

Note : It was thought preferable to investigate phosphate fixation on separate samples of the original soils rather than to determine phosphate on the *residual* potted soils sifted free of roots at the completion of the pot experiments, for the reason that the crops of Sudan Grass remove varying, and in some cases probably large, amounts of phosphate from the soil during growth. A test applied to one of the soils (Maracas Sand) demonstrated that this actually was the case ; the Truog phosphate content of the residual soil after sifting out the roots was only about 30 per cent. of that of the same soil treated in the laboratory in the manner described.

Results : The results obtained in the comparative phosphate fixation experiment are given in Table IV. Data both for unlimed and for limed soils are included. The liming was carried out by first mixing the necessary amounts of finely-divided calcium carbonate with water, and then passing in carbonic-oxide gas until most of the carbonate had been converted into soluble bicarbonate. The liquid was then mixed with the soil to form a thin paste before the phosphate solutions were applied. The data are plotted as graphs (white line curves) on the diagrams across the black columns that represented the yields of dry matter given by the different culture-treatments.

TABLE IV.—COMPARATIVE PHOSPHATE ABSORBING CAPACITIES

Results expressed as parts per million P_2O_5, determined by Truog's method

Soil	Dosages of superphosphate manure added							
	(*a*) *cwt. per acre*	1	2	4	6	9	12	18	28
	(*b*) *parts per million of soil* (P_2O_5)	22	44	88	132	198	264	396	616
(A) *Princes Town Heavy Clay*									
Amount extracted (p.p.m.)		5	15	31	50	100	105	191	245
Amount absorbed		17	29	57	82	98	159	205	371
Percentage absorbed		77%	66%	65%	62%	49%	60%	52%	60%
(B) *Talparo (Red) Clay*									
Amount extracted (p.p.m.)		10	11	18	33	46	88	137	214
Amount absorbed		12	33	70	99	152	176	259	402
Percentage absorbed		54%	75%	79%	75%	77%	66%	65%	65%
(B) *L. Ditto. Limed*									
Amount extracted (p.p.m.)		2	3	5	14	24	29	59	81
Amount absorbed		20	41	83	118	174	235	337	535
Percentage absorbed		91%	93%	95%	89%	88%	89%	85%	86%
(C) *Volcanic Ash*									
Amount extracted (p.p.m.)		5	8	21	34	63	73	141	286
Amount absorbed		17	36	67	98	135	191	255	330
Percentage absorbed		77%	82%	76%	74%	68%	72%	64%	53%
(D) *Sangre Grande Silty Clay*									
Amount extracted (p.p.m.)		4	4	13	26	37	42	86	159
Amount absorbed		18	40	75	106	161	222	310	457
Percentage absorbed		82%	90%	85%	80%	81%	84%	79%	74%
(D) *L. Ditto. Limed*									
Amount extracted (p.p.m.)		3	5	17	28	59	76	114	159
Amount absorbed		19	39	71	104	139	188	282	457
Percentage absorbed		86%	88%	80%	78%	70%	71%	71%	74%
(E) *Maracas Sand*									
Amount extracted (p.p.m.)		11	18	20	39	54	81	145	266
Amount absorbed		11	26	68	93	144	183	251	350
Percentage absorbed		50%	59%	77%	70%	72%	69%	63%	57%
(F) *Cunupia Clay*									
Amount extracted (p.p.m.)		13	12	33	48	63	53	106	179
Amount absorbed		9	32	55	84	135	211	290	437
Percentage absorbed		41%	73%	62%	63%	68%	80%	73%	71%
(F) *L. Ditto. Limed*									
Amount extracted (p.p.m.)		26	34	46	64	132	154	262	372
Amount absorbed		—	10	42	68	66	110	134	244
Percentage absorbed		—	23%	47%	51%	33%	42%	34%	39%

(IV) Discussion of Results

The consideration of experimental results may most conveniently be made separately for each soil in turn.

(A) Princes Town Heavy Clay (Subsoil)

This soil is evidently capable of absorbing appreciable amounts of phosphate (average experimental value, 61 per cent.) under the imposed arbitrary conditions (Table IV). This property may perhaps be attributed to interaction with free calcium carbonate known to be present in fair abundance (about 8 per cent.) in this sample. Reference to the cropping data diagrams showing the effects of superphosphate indicate that the yield of Sudan Grass increases up to about 60 g. of dry matter with successive increments of manure up to 9 cwt. acre, corresponding to a minimum experimental phosphate content of 95 p.pm. P_2O_5. The Sudan Grass crop was thus more than quadrupled by the addition of this amount of manure, assuming the presence of excess of available soil nitrogen. There was no significant additional yield given by phosphate dosages greater than 9 cwt. acre with this soil.

Increasing dosages of phosphate manure were accompanied by increases in the average number of tillers per plant which rose from 1.0 in the no-phosphate treatment to over 3.0 in the high-dosage treatments. An important cause of the greatly increased crop weight is thus the production of tillers apparently induced by phosphate additions. Furthermore, the root-system probably functions with greater efficiency in the high-phosphate cultures in which the ratio of weight of tops produced to weight of roots shows a marked increase with increasing phosphate additions. The yield values are somewhat erratic, however, as could only be expected, but the trends seems quite definite. Unfortunately, the cultures could not be replicated because of the limited number of Mitscherlich pots available. Watering too was erratic since the daily additions of water were merely guessed and not controlled by periodic weighings.

The practical significance of the results described above is likely to be very great. It is well known that sugar-cane growing on eroded marly hilltops often fails to respond to nitrogenous manuring. The plants are stunted and their leaves frequently show lime-induced chlorosis. By applying heavy dressings of superphosphate, along with the customary dressings of ammonium sulphate, much better growth and much larger yields should be obtained. Moreover, provided the trash is not burnt, the humic content of the soil might rapidly be raised by successive crops of sugar-cane so that the eroded areas might eventually recover their former fertility through the development of a new organic soil profile. It is interesting to note that preliminary field experiments along these lines have recently given most promising results in Trinidad.

(B) Talparo (Red) Clay

This soil-type is notoriously a strong phosphate fixer by virtue of its high content of active hydrous ferric oxide which forms insoluble ferric phosphate when brought into contact with soluble phosphates in solution. The example studied gave an average experimental value for degree of phosphate absorption of about 72 per cent. (Table IV). The cropping data indicated that the growth of Sudan Grass is negligible until a dosage of 9 cwt. acre superphosphate has been added. The yield even then is relatively very low (only 9 g. dry matter). Higher dosages gave correspondingly higher yields up to a maximum of 26 g. dry matter for the largest dressing. The corresponding available phosphate value was 50 p.p.m.

The average tiller count increased from *zero* to 2.5 for the 9 cwt. dosage and to over 5 tillers per plant for the largest dosage. The low yield level reached even with high dosages of phosphatic manure suggests that some restraining or limiting factor is operating; the next experiment indicates that this may be either an excessive degree of acidity or a shortage of nutrient calcium.

Effect of liming: The limed soil apparently absorbed considerably more phosphate (89 per cent. Table IV) under the arbitrary experimental conditions than the unlimed soil. This is unexpected. In theory, liming should reduce the phosphate-fixing propensity of ferruginous acid soils. Perhaps in this case the lime had not fully reacted with the soil,* or else, too great an excess of lime had been added which would take up a considerable amount of phosphate under the induced highly alkaline conditions. An actual test indeed showed that the experimentally-limed soil contained 1.4 per cent. of free carbonate which might be sufficient to account for the result obtained. It does not necessarily follow, however, that the liming of the *original* soil in the pot-test was similarly ineffective in that it failed to diminish the fixation of added phosphate, or that soil had also been overlimed. The yield data in any case show very great benefits from liming. The results obtained closely resemble those given by the last soil. The yield of the limed red soil without phosphate was about 3.4 g., but with increasing dosages of superphosphate it rose progressively to a maximum of 60 g., representing a 16-fold increase for dosages of phosphate manure of 9 cwt. acre or over. As before, an important effect of the high phosphate treatment was the raising of the tiller count from an average of 0.4 to near 3.0, and of the weight-ratio of tops to roots from about 1.8 to over 4.0. Dosages of phosphate manure above 9 cwt. acre failed to produce any significantly greater yield just as in the case of the Princes Town Heavy Clay sub-soil. The maximum yield corresponded with an experimental phosphate level of about 28 p.p.m.

* The degree of saturation by lime in this soil before liming was found by experiment to be about 53 per cent. After liming it was found to be 100 per cent. The method used for measuring saturation degree involved the determination of exchangeable calcium

The mechanism of the remarkable effect of lime on the yielding capacity of Talparo (Red) Clay soil cannot be explained on the limited evidence available and much further investigation would be needed to provide the information needed. If it be true that a large amount of phosphate is actually fixed by the limed soil, and that maximum yield may be obtained with a level of available phosphate of only 30 p.p.m., then the increase in yield obtained by liming and phosphating may be attributed to the great increase in *nutrient calcium* provided by the combined treatment. The Talparo (Red) Clay characteristically contains a very low amount of exchangeable calcium, as has been demonstrated, but there is considerable variation in this quantity for different samples, since some contain abundant gypsum (calcium sulphate hydrate) that theoretically should greatly raise the exchangeable calcium status of the soil containing it.

On the available evidence, then, there would seem to be no doubt that phosphate is closely involved in the very high yield increments of Sudan Grass which are obtained when Talparo (Red) Clay soil is treated with large dressings of soluble phosphate manure after liming, provided an adequate amount of available nitrogen is also present or supplied at the same time.

The great practical significance of this finding in connection with sugar-cane growing has recently been demonstrated by field experiments carried out on typical Talparo (Red) Clay in Trinidad. The exact requirements of phosphate, nitrogen, and lime for the different areas of variable red soil represented in the cane lands of the Island remain to be worked out by means of specific field experiments designed in accordance with the laboratory and greenhouse data discussed above.

(C) St. Vincent Volcanic Ash (Subsoil)

This coarse-grained fresh-mineral soil parent material appears to be capable of absorbing a fair amount (70 per cent. Table IV) of phosphate even though it contains but small quantities of colloidal matter and active hydrous ferric oxide which is only produced in this soil-type after considerable weathering has gone on. In spite of the relatively high values that most samples of Recent Volcanic Ash give with the Truog test, the yields obtained in the pot-cultures from which phosphate manure is withheld were very low. In the present series of tests, the yields of Sudan Grass were increased progressively from 1.8 g. to 61.5 g. (a 34-fold increase) by increasing dosages of superphosphate up to 4 cwt. acre. (Sufficient soil was not available for setting up more than 4 cultures.) The tiller count was increased from 0.5 to 1.6 but the ratio of tops to roots was not altered significantly.

Evidently little response to nitrogenous manuring can be expected from Recent Volcanic Ash unless phosphatic manure is applied in addition. The pot-tests indicate that marked response may be obtained with only 4 cwt. acre of superphosphate, provided heavy dressings of nitrogenous manure are also given. There is no need for lime nor potassic manure for high production with this soil-type. Unfortunately no field experiments based on these findings have yet been carried out in St. Vincent.

(D) Sangre Grande Silty-Clay

This alluvial soil, widespread in northern Trinidad, is becoming more and more important as a peasants' garden soil following the abandonment and the fragmentation of derelict cacao estates, particularly those occurring over the flood plains of the upper part of the Caroni River system. In future years this soil will doubtless be employed more and more for sugar-cane growing as its level of fertility falls.

According to the results of our comparative trials, the soil possesses a high phosphate-absorbing capacity, of the order of 82 per cent. (Table IV) which is even higher than that shown by Talparo (Red) Clay soil. Its ochre-yellow colour suggests that it may contain a considerable amount of highly hydrous ferric oxide (limonite) which would account for its phosphate-absorbing propensity.

Reference to the cropping data show that the particular sample of Sangre Grande Silty-Clay examined (which was formerly under cacao but has been growing peasants' crops for many years), though containing only a small amount of available phosphate (12 p.p.m.), yet gave a fair yield of Sudan Grass (21 g.) without the addition of phosphatic manure. When superphosphate was supplied, the yield was doubled, however, even with only one cwt. per acre of manure. It was not increased significantly with further phosphate additions, however, the biggest yields attained being about 52 g. for the 9 cwt. acre dressing, and 58 g. for 28 cwt. acre addition, but the data are somewhat erratic and should not be interpreted too literally.

Effect of liming: The limed soil apparently absorbed a lesser amount of phosphate than the unlimed soil (Table IV). It contained a slight excess (0.4 per cent.) of free calcium carbonate which is not sufficient to account for the fixation. The yields obtained from it, both without and with increasing dosages of phosphatic manure, were somewhat similar to those given by the unlimed soil. The liming thus seems not to have conferred any particular benefit. The data, as before, are erratic, and no great reliance can be placed in them. This soil-type, by reason of its increasing agricultural importance, deserves further study.

Repeated analysis have shown that Sangre Grande Silty-Clay is normally deficient in available phosphate and possesses the property of fixing phosphate so that it should respond readily to phosphate manuring. Its lime requirement is very variable, however, and the effects of adding phosphate to the limed soil are somewhat obscure. The soil-type as a whole is at present passing through a transition stage from a forest or cacao soil to an open field sugar-cane soil. Its organic matter component is therefore undergoing

deterioration, both quantitatively and qualitatively, and this may partly account for the peculiar phosphate relationships of its different developmental phases.

(E) Maracas Sand (Detrital Phase)

This soil occurs as a narrow strip adjacent to the foot-hill belt running along the western part of the Northern Range of Trinidad. It comprises most of the land of the College Farm, the Cotton Research Station and the house-lots in St. Augustine. It is very variable in mechanical composition, and ranges from fine micaceous kaolinic silt to coarse quartzose gravel. The sample examined was a fine sandy soil containing about 50 per cent. of silt and clay (Table I). It has an available phosphate content of only 8 p.p.m. It showed an appreciable phosphate-absorbing capacity (65 per cent.) when the arbitrary test was applied to it (Table IV).

The yield data indicate that maximum production of Sudan Grass may be expected with only 4 cwt. acre of superphosphate. The yield without added phosphate was very low (1.1 g.). It increased to 15 g. with 1 cwt. acre of superphosphate, then to 26 g. with 2 cwt. acre and to 40 g. with 4 cwt. acre. Higher dosages gave no further increment. Maximum yield with 4 cwt. acre superphosphate manure corresponds to an available phosphate level of 30 p.p.m. Tiller counts increase with increasing phosphate additions but weight ratios of tops to roots tend to diminish.

It is interesting to compare the information regarding the fertility status of Maracas Sand soil obtained from this investigation with the conclusions reached concerning the nutrient requirements of this same soil-type based on the findings of the Permanent Manurial Experiment which was begun in 1931 at the College Farm and is still in being.* The original soil of the unmanured (control) plot at the beginning contained 38 p.p.m. of available phosphate and after 12 years, 30 p.p.m. The standard unit dressing of superphosphate applied to each crop in this experiment was 1½ cwt. acre at first but it was increased in 1941 to 2 cwt. acre. The following facts emerged regarding the effect of phosphate manure on the large number of crops grown in the first period. (1) That the unit dressing "adequately made up for crop usage and leaching losses", and (2) that "all the treatments which contained (unit dosages of) superphosphate proved adequate in satisfying the phosphate requirements".... In the second period, during which the unit dosage was raised to 2 cwt. acre, it was found that, "in the absence of lime, the omission of phosphate from the complete mineral dressing appears to have been beneficial", varying from slight to large. It was concluded that "phosphate deficiency is not likely to occur", since "the inclusion of phosphate in manurial dressings has on the whole given disappointing results". It appears from these observations that, either the soil of the experiment plots differs significantly from that examined in the recent pot-tests, or that the benefits from phosphate manuring in the Permanent Manurial Experiment might have been greater had the unit dosage of nitrogenous manure been larger. This was only 1 cwt. *per crop* in the first period but it was raised to 3 cwt. acre *per crop* in the second period. The first possibility is rejected on the grounds that the soil-type is the same and the chemical analytical data are very similar for the two soils. The second might well explain the discrepancy, and it is suggested that a critical manurial experiment involving several levels of nitrogen and phosphate be carried out on College Farm soil to settle the matter. Whether or no the large dressings of manure needed to give maximum returns would be economic should be determined by costing.

(F) Cunupia Clay

This soil occurs on most sugar estates in the Northern Plain of Trinidad. It is perhaps the most fertile of the northern clay soils, though not necessarily the most productive because of its generally unsatisfactory water relations attributed to its low-lying position and unsatisfactory physical structure. The analytical data given in Table I for Cunupia Clay are probably typical. They show that the reaction is nearly neutral so that the lime status is doubtless good. Available phosphate is relatively abundant, the value 84 p.p.m. being nearly three times as high as what would be regarded as adequate for sugar-cane. The phosphate-absorbing capacity of this soil was found to be relatively low (Table IV).

It would not be expected therefore that the Cunupia Clay sample would respond appreciably to phosphate treatment; the pot-test data substantiate this assumption. The yield of Sudan Grass without phosphate addition was 36 g. which is the highest given by any of the untreated soils. With the addition of 4 to 12 cwt. acre of phosphatic manure, the yield was raised to between 50 and 60 g., and with the highest dosages (18 and 28 cwt. acre) it was raised to 70 g., or double the yield without phosphate.

It is thus possible that, in the field, treatment of this soil with dosages of superphosphate of 4 cwt. per acre or more may produce remunerative increases in the yield of sugar-cane. No critical experiments to test this possibility have yet been attempted as far as the writer is aware.

Effect of liming: The limed sample of Cunupia Clay (which contained an excess of only 0.3 per cent. of carbonate) showed little phosphate absorption in the comparative test, yet the yields of Sudan Grass were considerably less when the limed soil was treated with phosphate than they were in the case of the unlimed soil. The unphosphated limed soil, however, gave a somewhat higher yield. While the actual numerical data are not reliable, being very erratic the yield trends indicate over-liming.

* The College Permanent Manurial Experiment. R. C. Wood and F. Hardy, *Trop. Agric. Trin.*, 1941, XVIII, pp. 48-61 The College Permanent Manurial Experiment, F. Hardy and L. J. C. Evans, *ibid.*, 1945, XXII, pp. 128-237.

Summary and General Conclusions

(1) Greenhouse tests have been carried out in Mitscherlich pots in order to observe the effect of increasing dosages of superphosphate manure (1, 2, 4, 6, 9, 12, 18 and 28 cwt. per acre) applied to samples of five different types of soil utilised for growing sugar-cane in Trinidad and one from St. Vincent. Each culture received a basal dressing equivalent to 8 cwt. ac. of ammonium sulphate and 2 cwt. ac. of potassium sulphate.

(2) The Trinidad soils comprised (i) black (eroded marl) and red clay soils common in the Ste. Madeleine sugar estates in the south, (ii) river clayey-alluvial derelict cacao soil being now increasingly utilised by peasants for cane-growing in the north, (iii) College Farm red sandy soil, and (iv) productive clay soil widespread in the Northern Plain sugar-cane estates.

(3) Each of these soils (except the Volcanic Ash and the Cunupia Clay) showed a marked shortage of available phosphate by the Truog chemical test. The Volcanic Ash had previously shown phosphate shortage by the Mitscherlich pot-test, in which respect it behaves abnormally. The Cunupia Clay showed no phosphate shortage by pot-tests; it is presumably well supplied with phosphate, possibly by having been dressed with filter-press mud. All the soils except two showed no potash shortage.

(4) Each experiment involved 10 pots; two contained untreated soil as control, the rest contained soil treated with basal nitrogen and potash and with increasing quantities of phosphate. In addition, three of the soils were limed to pH 7.2 and then treated with manures in the same way. The treated soils were wetted and set aside for a fortnight to allow time for the manures to react with the soil.

(5) The indicator plant was Sudan Grass. The seedlings were thinned out to 35 per pot. The cultures were watered twice a day. The crops were reaped when 12 weeks old. Dried stems and roots were weighed separately.

(6) Phosphate fixation was measured in the laboratory on each sample by an arbitrary comparative chemical method. All the soils except the limed Cunupia Clay showed high phosphate fixing capacity.

(7) The pot-test data showed that progressively-increasing yields of Sudan Grass are given with increasing quantities of superphosphate up to an optimum of about 9 cwt. per acre, above which no significantly greater yields were obtained. In each case, the increase was associated with the formation of tillers whose average number per plant rose greatly with the higher dosages of phosphate manure.

(8) Liming greatly benefitted the highly acid red clay soil and gave a much enhanced phosphate effect. It did not benefit the other two soils that were limed.

(9) Failure to obtain response to soluble phosphatic manures, which has been the general experience for sugar-cane soils of Trinidad in the past, in many cases may therefore be explained by the relatively low dressings applied. It is urged that, in future field experiments, the effect of high-phosphate treatment, combined with high nitrogen treatment, on both unlimed and limed soil, be fully examined.

Explanation of Diagram

(1) This diagram records graphically the yield data obtained with increasing phosphate treatments in pot experiments carried out on six sugar-cane soils of which all but one (Volcanic Ash) occur in Trinidad. Data for three of the soils, limed to pH 7.2, are also given.

(2) Each *vertical black column* represents the yield in grams of oven-dried stems of Sudan Grass, reaped after flowering when 12 weeks old.

(3) The phosphate treatments, (superphosphate) were :—

Column 1	No addition
Column 2	No addition
Column 3	1 cwt. ac.
Column 4	2 cwt. ac.
Column 5	4 cwt. ac.
Column 6	6 cwt. ac.
Column 7	9 cwt. ac.
Column 8	12 cwt. ac.
Column 9	18 cwt. ac.
Column 10	28 cwt. ac.

A basal dressing consisting of ammonium sulphase, 8 cwt. ac., and potassium sulphate 2 cwt. ac., was given to each culture except the first two (controls).

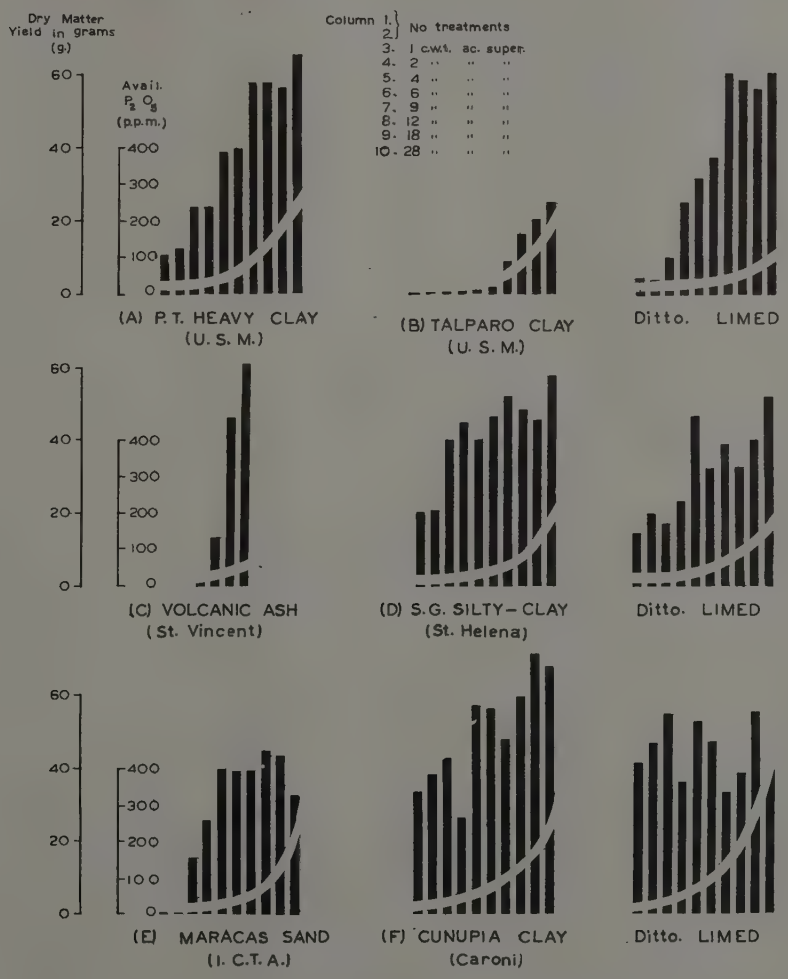
(4) The *white curved lines* across the sets of yield columns indicate the amounts of phosphate extractable by Truog's reagent from samples of soil proportionately treated with sodium phosphate solutions under laboratory conditions conducive to phosphate fixation, so as to imitate the graded dosages of superphosphate added to the cultures.

Results

(5) The black and red Ste. Madeleine soils and the St. Vincent volcanic ash (A), (B), (C), show marked response to increasing dosages of superphosphate. The optimum dressing for the first two when excess of nitrogen and potash is also supplied is about 9 cwt. per acre. Liming greatly increases the response of the red soil to phosphate.

(6) The other soils gave erratic results though they too show response to increasing dosages of superphosphate, except Cunupia Clay (D) which initially contained adequate phosphate.

EFFECTS OF INCREASING DOSAGES OF PHOSPHATIC MANURE ON YIELD OF SUDAN GRASS IN POT CULTURES



MAIZE POPULATION AND YIELD IN JAMAICA

BY

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Introduction

Maize has been cultivated in Jamaica since aboriginal times, but it is notorious that normal and even maximum yields compare very poorly with those obtained in temperate climates as well as elsewhere in the tropics. The average yield throughout the Island probably lies between 12 and 15 bushels (720-900 lbs.) per acre, yields of 20 bushels are considered normal and over 30, exceptional.

As a result of the necessity for increased home production of food crops imposed upon Jamaica by the war, a seed corn production scheme was instituted by the Department of Agriculture at the end of 1939 with the primary object of breeding a yellow hulled corn suitable for meal production and adapted to local conditions, and at the same time an opportunity arose to endeavour to improve yield. The first objective was rapidly attained by careful mass selection, but it has rapidly become apparent that no significant increase in yield was forthcoming. It had, therefore, to be concluded that the unconscious selection carried out by the local farmer, who has been dependent on his own crop for his seed, has produced as much improvement in yield as was possible by mass selection with the genetic material available.

Population Samples

In the course of the seed improvement programme it soon became obvious that with the established planting practice a very low population at harvest resulted, though this practice appeared adequate to produce a satisfactory bearing by the individual plant under favourable conditions. In order to obtain a more precise estimate of plant loss, population counts were made at harvest on four fields during 1944-5.

Ten one chain samples were selected at random through each field, and the number of plants in each with 0, 1 and 2 ears were counted (Table I). Field No. 1 was situated at Grove Farm in Saint Catherine, the variety M.L.J. was planted at 3ft. × 1ft. and harvested in July 1944. Field No. 2 at Twickenham Park in Saint Catherine was planted with the variety M.J., spaced 2ft. × 1ft. and harvested in March 1945. Field No. 3 at Grove Place in Manchester was planted with the J.S.Y. variety, spaced 2ft. × 1ft. and harvested in July 1945. Field No. 4 at Twickenham Park, planted with M.J. at 2½ft. × 1ft. was also harvested in July 1945.

The acre yields for fields 1 and 4 were respectively 24 and 22 bushels. Field 2 was a failure owing to poor germination and subsequent caterpillar damage. The crops in fields 1 and 4 were good for the districts in which they were situated and in field 3, average. The standard deviation is given in indication that the method employed yielded a representative sample.

For the four samples the mean stand at harvest expressed as a percentage of the theoretical population was 37.5%, while admittedly one crop failed, the best stand, on field 4, was no more than 53.8%. Furthermore, of the surviving plants, on an average 15.2% were barren, the nett result of planting 100 seeds was, therefore, 31.8 bearing plants. As three different varieties were involved the cause was unlikely to be genetical. Climate and cultural factors alone are inadequate to account for the plant loss as the four samples were distributed over three successive crops in three different areas. The incidence of pests and diseases appeared to be a likely cause of the situation. Although there are several well known diseases and pests of corn in Jamaica none usually appears sufficient in intensity to account for the existing situation. The following investigations were therefore undertaken as a preliminary enquiry into the factors responsible for reduction of plant population from sowing to harvest.

The area selected was situated at the Hope Experiment Station, a district well outside the limits of the best corn producing areas and where a yield of 20 bushels would be regarded as good. The area is one where, though the total rainfall is adequate for corn production, owing to its irregular distribution there is a liability to drought and intermittent

Table I

Field	Mean No. plants at harvest	S.D.	Percentage stand	Percentage of plants at harvest			Total
				With 0	1	2 ears	
1	30.5	7.4	46.2	4.9	85.2	9.8	99.9
2	12.9	2.4	19.5	27.9	58.1	13.9	99.9
3	20.0	1.3	30.3	17.0	76.5	6.5	100.0
4	35.5	8.9	53.8	18.3	78.6	3.1	100.0
Mean...	24.7	—	37.5	15.2	77.5	7.3	100.0

irrigation is normally employed. Furthermore, insect damage, especially from *Laphygma frugiperda* A. & S., is common and regular spraying with lead arsenate-nicotine is necessary.

First Experiment

The following experiment was conducted by Dr. G. B. Wilson during the writer's absence in the Spring of 1945. 1000 grains of untreated J.S.Y. seed were planted at the Hope Experiment Station in 50 rows of 20 plants each at a depth of 1½ ins. Germination was allowed to proceed for 14 days at the end of which all seeds which had not produced visible seedlings were searched for and recorded as missing, eaten, rotted, etc. Surviving plants were thereafter kept under observation. The soil was poor, but no fertiliser was used and the season was exceptionally dry (11.75 ins. rain fell on 46 days during the crop of which 3.65 ins. fell over 16 days in the last month). These factors account to some extent for the poor vigour of the plants and the low yield of grain, equivalent to 10 bushels per acre. The results are summarised in Table II.

Referring to this table, 10.5% of the seed were never recovered (column 1) having probably been removed by rodents, evidence of whose action was found on 3.8% of the seed (2); 85.7% of the seed therefore probably commenced germination. 1.9% rotted in process of germination (3) and 1.8% was eaten, mainly by ants and millipedes before penetrating the surface (4). The above-ground germination was therefore 82%. Damping off (5) and insects (6), mainly crickets, destroyed a further 6.0% as young seedlings. Owing partly to stalk rot (undiagnosed) and heart rot (*v. infra*) but mainly to cattle breaking into the field, only 57% survived to tasseling. Thereafter stalk rot, (9 and part of 10), accounted for a further 3.0% which, with other losses, (11 to 14), resulted in 36.9% of the original planting bearing ears (15-16). The mosaic dwarfs were probably due partly to virus disease and partly to genetic factors. About half of the 14.4% barren plants (14) were unthrifty and undersized but the remainder were apparently fully developed and may have been affected by disease late in life.

Second Experiment

Cultural: A further experiment was then commenced in the Autumn of 1945. The area planted was just over a ½ acre in size and planting was carried out on September 18th, 1945; fertiliser was applied at planting at the rate of 2 cwts. of muriate of potash and 2 cwts. of nitrate of soda per acre; the crop was reaped on January 25th, 1946. The rainfall over this period totalled 31.51 ins. and was well distributed (54 rainy days), no recourse to irrigation being necessary. The period was exceptionally suitable climatically for corn. The seed was of a new variety (RVTM) in process of selection, recently reaped, selected and graded, and in sound condition. Seed was planted in 4 in. furrows at 2½ ft. between rows and 1½ ft. between hills within the row, 2 seeds being planted to the hill. Prior to planting the seed was dusted with Agrosan G. at the rate of 2 ozs. per bushel. Planting was done by hand at approximately 1in. depth by experienced labour. The tilth of the seed bed was good and normal cultivation was employed. One inter row cultivation using a small mule drawn harrow was carried out to control weeds and the rows were hand hoed. The hills were moulded up on October 6th, at the time of harrowing and no further cultivation was found necessary.

Experimental: For the purpose of keeping individual plant record, ten plots, each a continuous section of row one chain in length, were selected at random throughout the field. Each plot should, therefore, have contained 44 hills, but owing to slight irregularity of spacing resulting from hand planting the number of hills varied and two and three hills were discarded at the ends of two rows in order that an average of 44 hills was obtained for the ten rows. Observations were commenced with a germination count on October 1st; thirteen days after planting (no supplying or thinning was done) and were continued at 3 day intervals until harvest. As before, records were kept of the death of individual plants and, as far as possible, the cause was determined. At harvest, counts were made of the plants bearing 0, 1 or 2 ears and the weights of dry husked ears and shelled grain were taken.

Table II

	Germination losses				Seedling losses		Plants killed					Ear losses		Ears			Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
	Seed failed and missing	Seed dug out	Seed rotted	Seed eaten	Damping off	Insects	Cattle	Heart rot	Stalk rot	Various	Mosaic dwarfs	Rats	Theft	Plants with 0	1	2	
Plants	105	38	19	18	40	20	151	12	17	42	16	4	5	144	258	111	1000
%	10.5	3.8	1.9	1.8	4.0	2.0	15.1	1.2	1.7	4.2	1.6	0.4	0.5	14.4	25.8	11.1	100

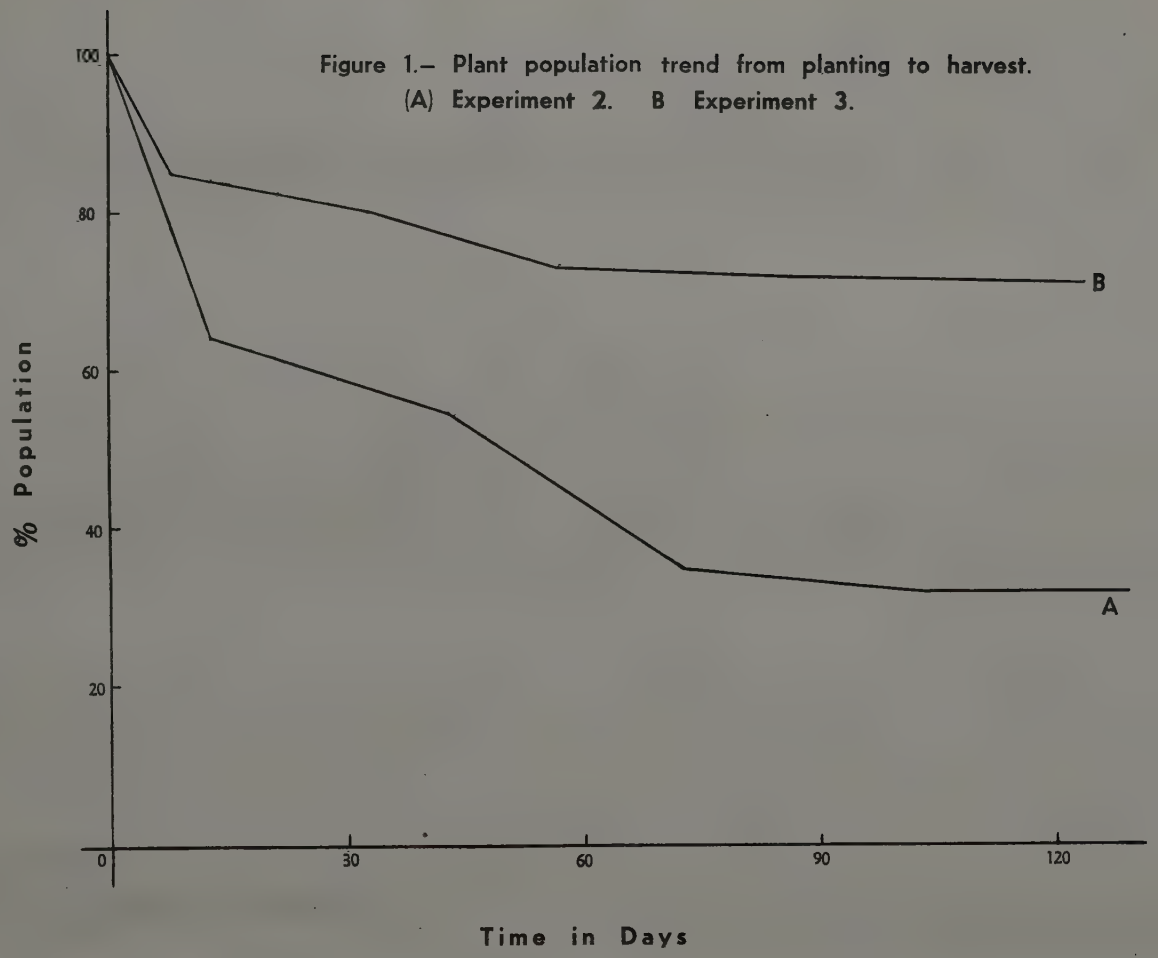

Figure 1.– Plant population trend from planting to harvest.
(A) Experiment 2. B Experiment 3.

Results. The population trend is shown in Table III which gives the number of plants per plot at intervals from germination to harvest.

Population. It is immediately apparent from perusal of Table III that over a third of the potential crop was lost between planting and germination. This cannot be ascribed to inferior seed as a germination test resulted in 97% healthy seedlings; neither was it due to unfavourable soil conditions, tilth was fine and the seed bed moist. It is possible that irregularity in depth of planting, which always accompanies hand planting, may have had some effect but it is unlikely that it was appreciable, as previous experiments using planting depths from 0 ins. to 6 ins., resulted in no variation in germination provided moisture requirements were satisfied. Examination of ungerminated seed in the ground, however, showed that a high percentage of that recovered had been damaged by pests. Mice had been responsible for eating the seed generally, ants were recovered from cavities occupying the site of the embryo, and evidence was found of cutting off of the plumule by millipedes. In contrast to the previous experiment no damage from cut worms and crickets was noted.

The subsequent fall in population is graphically represented in Fig. 1. After the initial drop at germination there is a steady fall in population during the first six weeks of growth but in the second month the rate increases. There is a slowing up in the third month and equilibrium is reached approximately three months after planting by which time the plants are fully grown and the ears are approaching maturity.

Observations on the causes of plant loss are recorded in Table IV which gives the number of plants killed in each plot from various causes.

Losses of Plants

Heart rot was evidently the principal cause of depopulation being responsible for over 45% reduction of germinated plants. It has not so far been fully diagnosed but consists of a soft rot of the heart leaf and growing point associated with bacterial infection. This disease is sporadic in occurrence and has only recently been recorded in Jamaica as serious on corn (Larter 1941). From casual observation of previous crops it was not previously thought that this disease has been responsible for more than a 5% loss of plants in Jamaica, it is probable, however, that a true average assessment would be nearer 10% and that it must be regarded, at least in certain areas, as a serious problem. This disease is most serious in effect when the plants are from 1½ ft. to 4 ft. high, the period of most rapid growth, which also coincides with the phase at which damage from *Laphygma* is usually most serious. It is possible that the two conditions are correlated; the toxic action of the insect frass or decomposing caterpillars may

Table III

Plot No.	1	2	3	4	5	6	7	8	9	10	Mean	S.D.	%
No. of hills ...	48	44	42	46	47	46	42	41	44	40	44	—	—
No. of seeds planted	96	88	84	92	94	92	84	82	88	80	88	—	100.0
No. of Plants at :													
1.10.45 ... (Germination)	48	70	53	68	58	62	67	51	60	27	56.4	12.7	64.1
31.10.45 ...	44	64	43	57	51	48	56	44	54	19	48.0	7.0	54.5
30.11.45 ...	39	40	12	27	29	35	35	31	42	15	30.5	10.2	34.7
31.12.45 ...	38	36	12	25	26	32	31	28	37	15	28.0	8.9	31.8
25.1.46 ... (Harvest)	38	36	12	25	26	32	31	28	37	15	28.0	8.9	31.8

Table IV

LOSSES OF PLANTS

Plot No.	1	2	3	4	5	6	7	8	9	10	Mean	Percentage
Plants Germinated ...	48	70	53	68	58	62	67	51	60	27	56.4	100.0
Heart rot	9	29	39	40	30	29	36	20	15	10	25.7	45.6
Stem rot	1	4	—	—	—	—	—	2	3	—	1.0	1.8
Caterpillar ...	—	—	1	1	—	—	—	—	2	1	0.5	0.9
Tillage	—	1	1	2	2	1	—	1	2	—	1.0	1.8
Various	—	—	—	—	—	—	—	—	1	1	0.2	0.3
Total	10	34	41	43	32	30	36	23	23	12	28.	50.3
Percentage ...	20.8	48.6	77.4	63.2	55.2	48.4	53.7	45.1	38.3	44.4	50.3	—

predispose the tissues to bacterial infection. It should be noted, however, that whereas heart rot was serious in this experiment caterpillar damage was negligible. Further investigation on this point is indicated.

The losses from stalk and basal rots were surprisingly low amounting to no more than 1% of the plants lost. It is possible, however, that only a small proportion of the cases were diagnosed as it is likely that infections resulting in diseases of this type did not always result in death before maturity. Among the 10 cases of this type noted a causative agent was isolated by E. B. Martyn and identified as *Pythium aphanidermatum* (Edsen) Fitzpat. It is to be expected that, in addition, some infection with *Diplodia zeae* (Schw.) Lév. and *Fusarium* spp. was present, as these fungi are almost invariably found as a cause of ear rot at harvest.

Caterpillar damage was considerably less than was expected, as, in the area where the experiment was conducted *Laphygma frugiperda* (A. & S.) is normally serious. This was due in part to regular spraying and probably in part to abundant rainfall, as serious caterpillar damage is generally associated with dry weather.

In commercial practice carelessness in weeding and moulding is often responsible for appreciable plant loss. On one occasion a loss of 13% of the population was counted, this however was exceptional, but a 5% loss is by no means uncommon. In the present experiment special supervision was used to minimize losses from this cause.

Yield. While a considerable loss of crop is accounted for by progressive depopulation a further appreciable loss was apparent at harvest due to barren plants and undersized ears.

Plants at Harvest

The important feature appearing from Table V is that 27.5% of the standing plants at harvest were barren. The cause thereof is undetermined. Many of these plants were undersized and it is probable, as suggested above, that among the principal causes are diseases such as stalk and root rots. In this connection the time factor in disease incidence is of interest. Of the deaths from heart rot, 27.6% occurred within 43 days of planting, 67.3% from the 44th to the 74th day and only 5.1% thereafter, whilst deaths from stalk rot all occurred between the 74th and 105th day.

It is noteworthy that several of the diseases known to contribute to depressed yields in Jamaica were not found on this occasion, as for example Smut (*Ustilago zeae*), Rust (*Puccinia sorghi*), Leaf Scorch (*Helminthosporium turcicum*), Leaf Spot (*Cercospora sorghi*), Ear Rots (*Diplodia zeae, Fusarium spp.*). Nor was damage from insects, which is often considerable e.g. earworm (*Heliothis obsoleta, Laphygma frugiperda*) and weevil (*Calandra oryzae*), of any consequence.

The yield of grain from the ten plots totalled 28.4 lbs. equivalent to just over 2¼ ozs. per bearing plant or 12½ bushels per acre. While this compares satisfactorily with the yield for the whole field (at the rate of 11 1/3 bushels per acre) it is evident that a high proportion of the ears were undersized. A good average ear in Jamaica gives 5 ozs. of grain and has been obtained in previous crops on the same field. As neither the cultural nor climatic conditions were likely to have operated unfavourably on the crop it is probable that this again is a reflection of the disease situation. The low seed yield per plant was not due to partially filled ears as is shown by the shelling percentage (lbs. grain per 100 lbs. ears) of 78%; the average for a good crop being about 80%.

Third Experiment

A third experiment was commenced in the Spring of 1946, on the same site as the second at Hope Experiment Station. The same variety RVTM was used; the seed was again dusted and was planted at the same spacing. Two seeding rates were used in order to determine the effect of planting four seeds to the hill and subsequently thinning as against two seeds to the hill. The field was, therefore, divided into alternating strips each 5 rows in width, each row being approximately 30 yards in length and extending across the width of the field. Alternate five row strips were planted at the two seeding rates giving six replications of each treatment. Planting, fertilizing and spraying were carried out as before. In contrast to the second experiment the weather during this one was extremely dry, the rainfall totalled 6 27 ins. distributed over 25 rainy days and it was, therefore, necessary to carry out regular irrigation. Planting was carried out on April 4th, 1946, and the crop was reaped on August 9th. The

Table V

PLANTS AT HARVEST

Plot No.	1	2	3	4	5	6	7	8	9	10	Mean	%
Plants with ears: 0	2	9	4	7	8	8	11	9	12	7	7.7	27.5
1	36	26	8	14	18	21	20	16	24	8	19.1	68.2
2	—	1	—	4	—	3	—	3	1	—	1.2	4.3
Total	38	36	12	25	26	32	31	28	37	15	28.0	100.0
Percentage bearing ...	94.7	75.0	66.6	72.0	69.2	75.0	64.5	67.9	67.6	53.3	72.5	—

overseeded plots were thinned to an average of two plants per hill retaining the more vigorous plants on May 23rd. Owing to the drought only one weeding was necessary and was carried out immediately prior to moulding at the end of April.

Prior to planting the land was ploughed in February and the whole area was harrowed once. Owing to a breakdown of equipment only half of the field could be cross harrowed, this was therefore made an opportunity of seeking an effect of intensive preplanting cultivation against the usual practice. The single harrowed half of the field (Section B) was only harrowed once again immediately prior to furrowing and planting with the result that the seed bed was coarser and potentially weedier than that of the double harrowed half (Section A) which was recultivated on three subsequent occasions with a Planet Junior cultivator prior to planting resulting in a fine clean seed bed. Of the twelve strip plots six were located in each differently prepared half of the field.

As before, for the purpose of keeping individual plant records continuous sections of rows, each involving 40 hills, were selected in each of the 12 plots. Similar observations were made on these sample rows to the previous experiment. Yield records of the whole plots were also kept.

Results. Table VI sets out the population trend from planting to harvest in the 12 sample rows each containing 40 hills and Table VII analyses the respective causes of loss at various stages of growth.

In all twelve rows losses between planting and germination amounted to 14.9% of the seed planted and were therefore considerably less than in the previous experiments. Of this the majority of plants (13.7%) were not recovered and were probably lost through some agency such as field mice which consumed the entire seed or removed it bodily from the hole in which it was planted. Losses of plants subsequent to germination were small totalling 8.9% of the seed planted, ascribable to eight different causes no one of which accounted for a loss of more than 2.1%. Heart rot, which caused such serious loss in the autumn of 1945, in the present experiment only resulted in a 2.0% loss. This reduction is probably related to the drought conditions which prevailed. It is of interest to note that in spite of the dry weather, spraying was effective in controlling *Laphygma* infestation and no deaths resulted from this cause.

Total plant losses on the two differently prepared halves of the field indicated a higher loss on Section A. If, however, the losses from Stalk and Collar rot are removed from the data the residual differences are not significant. The indication is that the only effect of the difference in preparation of the seed bed was a greater plant loss from Stalk and Collar rot on the better prepared land; in the absence of replications of the two treatments this effect should be subject to confirmation by further experimentation before acceptance.

There was no difference in total percentage losses from plots planted at the double and single seed rates. Examination of the losses from individual

Table VI

NUMBER OF PLANTS FROM PLANTING TO HARVEST

TOTALS OF THREE PLOTS

Land Preparation	(A) Good seed bed		(B) Poor seed bed		Totals			
					Preparation		Seeding	
Seeds per hill	4	2	4	2	(A)	(B)	4	2
Seeds planted April 4th ...	480	240	480	240	720	720	960	480
Germination 12th ...	387	222	400	216	609	616	787	438
May 7th ...	369	202	387	197	571	584	756	399
After thinning ,, 31st ...	232	195	241	191	427	432	473	386
June 30th ...	228	188	241	190	416	431	469	378
Harvest Aug. 6th ...	226	183	241	186	409	427	467	369
Loss at germination ...	93	18	80	24	111	104	173	42
Percentage					**15.4**	**14.4**	**18.0**	**8.7**
Loss after germination (i) ...	41	39	19	30	80	49	60	69
Percentage					**11.1**	**6.8**	**6.2**	**14.4**
Total loss	134	57	99	54	191	153	233	111
Percentage					**26.5**	**21.2**	**24.2**	**23.1**

(i) excluding plants removed at thinning.

causes, however, indicates two significant differences. There is a greater tendency to mortality from damping off in plots planted with two seeds to the hole, for which no explanation is readily available. On the other hand there is a very significantly higher loss of seed between germination and planting in plots with 4 seeds to the hole. As the greater proportion of this loss is attributable to rodents it would appear that they are attracted to those plots which were more heavily seeded.

Although the total depopulation was less in this than in the second experiment the characteristics of the trend are identical (Fig. 1). As before the maximum rate of mortality occurs at germination and a slight acceleration appears in the second month of growth, thereafter there is a steady decline in mortality rate. The increase in the second month of growth is due to heart rot, for in both experiments it is during this period that the great majority of the total of such deaths occur and the converse is equally true, that the majority of deaths occurring in this period are due to heart rot.

Yield. Crop losses at harvest due to barren plants (28.4%) were again high amounting to 24.4% of potential ears allowing an average bearing of one ear per plant (Table VIII).

Good seed bed preparation (Section A) resulted in a considerable reduction of barren plants and an increase in plants bearing two ears as compared with the poorly prepared seed bed (Section B). It is to be noted that on the denser planted half of Section B there was a higher percentage of barren plants than on the corresponding half of Section A. This may possibly be attributed to root competition as Section B was considerably more weedy than Section A in the early stages before moulding and the additional root competition resultant upon denser planting may have had a greater effect on that section; on the other hand root disease may have been the deciding factor. It is doubtful if the 3.7% increase in barrenness in Section A associated with denser planting is of significance.

There is a consistent increase in number of ears, weight of ears, husk, grain and stover on the double planted as compared with the single planted ground (Table IX). With the exception of the stover this increase is, however, of doubtful significance on the poor land but is marked on the well prepared seed bed. A greater increase in yield has resulted from care in seed bed preparation than from denser planting. These increases are due mainly to an increase in the number of ears at harvest rather than increase

Table VII

PERCENTAGE OF PLANTS LOST FROM VARIOUS CAUSES

	No. of Seeds planted	Seeds		Plants								
		Rotted	Missing	Damping off	Ants	Mice	Cutworm	Heart rot	Wilt	Stalk and Collar rot	Tillage	Total
Good seed bed (A) ...	720	1.5	13.7	1.8	0.3	1.0	1.7	2.4	0.4	3.2	0.4	26.5
Poor seed bed (B)	720	1.0	13.5	1.7	—	—	0.8	1.7	0.7	1.0	1.0	21.2
Thick planting	960	0.8	17.2	0.7	0.2	—	1.1	1.9	0.4	1.3	0.6	24.2
Thin planting	480	2.1	6.7	3.7	—	1.5	1.5	2.2	0.8	3.7	0.8	23.1
For all twelve rows ...	1,440	1.2	13.7	1.7	0.1	0.5	1.2	2.0	0.6	2.1	0.7	23.9

Table VIII

BEARING OF PLANTS OF HARVEST

Land Preparation		(A) Good seed bed		(B) Poor seed bed		Totals				
						Preparation		Seeding		
Seeds per hill		4	2	4	2	(A)	(B)	4	2	
Plants with ears	0	47	45	94	51	92	145	141	96	237
	1	166	123	145	132	289	277	311	255	566
	2	13	15	2	3	28	5	15	18	33
Total		226	183	241	186	409	427	467	369	836
Percentage bearing plants		79.1	75.4	61.0	72.6	77.4	66.0	69.7	73.9	71.6

in ear weight. Over all there is no difference in ear weight from the single and double plantings owing to compensating differences on the good and poor seed beds, in the former case the single planting produced the heavier ears and in the latter the double planting did so. This reversal of behaviour is explicable in various ways but in view of its doubtful significance should be the subject of further investigation. As regards the effect of land preparation on ear weight the totals strongly suggest that good preparation has produced heavier ears.

The foregoing results accrued from observations on the experimental plots, twelve rows of equal length taken at random through the field. Yield records for the whole field were also taken and are summarised in Table X.

These figures confirm those already analysed differing only slightly in degree. For instance the whole field yielded at the rate of 16.8 bushels per acre, as compared with 18.1 bushels per acre from the selected experimental rows; and the rate of yield from the whole field on doubly planted well prepared land of 22.9 bushels and singly planted poorly prepared land of 12.1 bushels are comparable with the figures previously computed, 25.6 and 11.9 bushels.

Conclusions

While it is admitted that the area in which the foregoing experiments were carried out is not a good one for maize production, yields of over 30 bushels per acre have been obtained there. Observation over a period of years of fields in the recognised corn areas of the country indicates that the problems there are essentially similar and the results set out herein are applicable. The present discussion can do no more than indicate the lines on which further investigation should be carried out to determine more specifically the dominant causes of yield depression and to devise remedial measures.

The losses at and immediately after germination amounted to 24.0%, 35.9% and 14.9% in the three experiments respectively; losses of plants subsequently were respectively 9.6%, 33.3% and in the third experiment, when adjustments are made for thinning, 10.9% (omitting the 15.1% loss in the first experiment from cattle damage) and finally, losses from barren plants at harvest were 14.4%, 8.7% and 24.6%. In other words only 36.9%, 23.1% and 62.3% of the seed planted (excluding thinned seed) survived to bear ears. The surviving population in the four preliminary observations

Table IX

YIELD IN LBS.

Land preparation	(A) Good seed bed		(B) Poor seed bed		Totals			
					Preparation		Seeding	
Seeds per hill	4	2	4	2	(A)	(B)	4	2
Number of ears	192	153	149	138	345	287	341	291
Weight unhusked ears (i)...	38.2	31.8	23.9	20.2	70.0	44.1	62.1	52.0
,, husked ears	33.4	28.4	20.5	17.5	61.8	38.0	53.9	45.9
,, grain	24.0	19.4	13.7	11.2	43.4	24.9	37.7	30.6
,, stover	62.6	57.4	59.9	45.1	120.0	105.0	122.5	102.5
Mean ear wt. (ozs.)	2.72	2.97	2.27	2.03	2.87	2.12	2.53	2.52

(i) ears partially dried.

Table X

YIELD IN LBS. FROM WHOLE FIELD

Land preparation	(A) Good seed bed		(B) Poor seed bed		Totals			
					Preparation		Seeding	
Seeds per hill	4	2	4	2	(A)	(B)	4	2
Unhusked ears	284.4	238.8	182.9	157.9	518.2	340.8	467.3	291.7
Husked ears (i)	248.3	207.2	156.1	136.6	455.5	292.7	404.4	343.8
Grain	174.9	142.1	104.4	91.6	317.0	196.0	279.3	233.7

(i) partially dried.

(Table I) varied from 19.5% to 53.8% averaging 37.5%. Even on the optimistic estimate of an average of 50% harvest the annual loss to Jamaican farming would be of the order of £125,000.

The losses around germination were ascribed to at least seven different causes, rodents, ants, millipedes, cutworms, crickets and damping off, no one of which, with the exception of field mice, could be held responsible for more than a 4.0% loss. With the use of an effective seed treatment a considerable increase in yield should be obtainable. Of the different treatments which have been tried, dusting with Agrosan G. has been adopted as standard practice with seed issued under the Government Seed Improvement Scheme. It is apparent from germination tests that this treatment gives a significantly higher percentage of healthy seedlings and reduces seed rot. Its effects are not, however, apparent in comparison of germination in the experiments described. This is probably due to a greater degree of damage from rodents in the second experiment in the control of which this dust would not then appear to be efficient. The most effective method so far tried as a deterrent to rats and field mice is the application of gas tar to the seed as described in Queensland (Anon. 1939). This has resulted in a considerable improvement in germination on the friable terra rossa soils on which a large proportion of the Jamaican corn crop is grown. Further experimentation on the use of tar with or without the combination of a recognised fungicide is certainly indicated. Other methods which have been tried include soaking the seed prior to sowing in Kerosene or aqueous extract of bitter wood (*Picraena excelsa*), but neither method has proved consistently effective though the latter is widely used in local commercial practice. Where insect and rodent damage is liable to be particularly serious the advisability of broadcasting as against drilling or row planting could be considered, though for other reasons the latter methods are to be preferred. Until effective control measures are worked out it is advisable that over seeding should be practiced. The present procedure of planting 12-16 lbs. seed per acre followed by supplying should be replaced by planting 30 lbs. seed per acre and thinning where necessary when moulding is carried out. Experience over several years has shown that supplying blanks is uneconomic, as, owing to competition with the original plants, a large proportion of supplies either fail to bear or produce poor undersized ears.

From establishment to harvest, plant losses are still considerable, but appear to be more variable from season to season than do the initial losses. They appear to be due mainly to disease in one form or other though in dry seasons *Laphygma frugiperda* may become the dominant factor. It has been proved in practice that effective control of this insect can be brought about by spraying. In so far as the disease situation is concerned 'Bacterial' heart rot stands out as being most damaging under suitable climatic conditions and control methods for this disease should be worked out. Of the other diseases recorded, with the information at present available, it is difficult to isolate any one as being particularly serious. Nevertheless, their cumulative effect was responsible in these experiments for plant mortality up to 10% in spite of the fact that several of the better known corn diseases e.g. rust and smut, were absent from these fields. Furthermore, it is probable that the more insidious and undiagnosed diseases such as root, collar and stalk rots were responsible for from 8% to 25% loss at harvest in barren plants. Perusal of Table I indicates that such losses are general, for in the four fields involved the percentages of barren plants varied from 4.9 to 27.9% averaging 17.0% of the standing plants. Even in the case of the more easily recognisable diseases such as rust, an infection of more than 80% of which has been observed, no data are available regarding the crop losses involved. It is obvious that a comprehensive survey of the pathology of the crop and the etiology of the diseases involved is required. Until further information is forthcoming it can only be advised that close attention be paid to field sanitation measures such as rogueing diseased plants (smut, mosaic, heart rot, etc.) and removal and destruction of the stover by burning or composting as soon as reaping is completed.

While many of the undetermined causes of poor yield of maize in Jamaica can undoubtedly be related to one or more of a number of undiagnosed diseases, it is quite clear that a considerable improvement can be effected as a result of experimentation along purely agronomic lines. The third experiment shows that losses from progressive depopulation can be offset by overseeding which resulted in a final population of 97.3% of the theoretical and in an increase in yield of approximately 25%. While such an increase masks the losses accruing from the disease situation, these are still present and this procedure must be regarded as an ameliorative and not a curative one. With proper control of the diseases involved further considerable increases in yield must be forthcoming.

An even more marked increase in grain yield (57.4%) was forthcoming through thorough preparation of the land prior to planting. It should be noted that denser planting on a good seed bed as compared with thinner planting on a poor seed bed has resulted in a cumulative increase in yield of grain of over 100%, representing a yield per acre of 25.6 bushels as against 11.9 bushels. The nett increase in monetary return to the farmer on account of such an increase with the present price of maize would be between three and four pounds per acre. It is to be expected that experimentation on the several other agronomic processes involved in corn cultivation would reveal further ways in which profit on the crop could be appreciably increased.

Summary

It is shown by population counts of commercial corn (maize) fields in Jamaica that the average stand at harvest is of the order of 50%.

Experimentation reveals that depopulation is due partly to pests, especially rodents, attacking newly sown seed (up to 36% loss), *Laphygma frugiperda* and heart rot (up to 45%) attacking the young plants and a complex of undiagnosed diseases killing older plants and rendering them barren (up to 25%).

Of these causes of loss only army worm is subject to efficient control in commercial practice. Thorough investigation of the disease situation is obviously necessary and effective seed treatment and pest control at planting is required. Tarring seed has proved useful in the last connection.

Pending such investigations losses from depopulation can be largely offset by overseeding and thinning which is considerably more satisfactory than supplying.

In addition it is shown that by relatively inexpensive improvements in seed bed preparation and planting over 100% increase in grain yield can be obtained, and it is inferred that proper attention to other aspects of cultivation should result in very large yield increases.

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Conduction of Rainfall by Plant Stems in a Tropical Rain Forest Water draining down stems of woody plants growing on Barro Colorado Island, Canal Zone, was collected by means of cups and measured. The amount of water collected was calculated to inches of water on the basis of the net area of the cup and expressed as percentage of the rainwater collected by the official rain gauge. The experiment covered a period of 13 days in August, 1938. A leafless control stem, equipped with a collecting cup, collected 80.0 to 104.2 per cent. as much water as the rain gauge. Cups installed on the stems of *Annona* and *Myriocarpa* trees, the former in the laboratory clearing and the latter in the rain forest, collected six to seven times more water than the rain gauge. Cups arranged in tandem on a stem of *Nothopanax* collected an amount of water consistent with their position. The smaller upper cups, which caught the water flowing down the leaves and smaller branches of the trimmed crown, collected an average of two and one-half times as much water as recorded by the rain gauge. The lower larger cup, into which water from a short portion of the stem and from a lateral group of leaves drained, collected on the average slightly more than a third as much water as the rain gauge. These *Nothopanax* plants possessed well developed mats of leafy liverworts and lichens. From the results it seems conclusive that during the rainy season in a tropical rain forest area an amount of water flows down the stems of woody plants sufficient to support a copious growth of epiphytes such as lichens, liverworts, mosses, and filmy ferns.

(*Bot. Gazette*, 101, 328).

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Grapefruit Storage Experiments

Two treatments tried in grapefruit storage experiments were: waxing alone (intended primarily to obviate shrinkage), and waxing after immersion in a 5% borax solution. The waxed fruit showed substantially less waste than the untreated fruit, presumably because the waxing process removes a number of mould spores from the fruit and prevents their making direct contact with the rind. The boraxed fruit showed less waste after 11 weeks' storage than the non-boraxed at 5 weeks, and the fruit in the two groups held from 13 to 14 weeks showed a loss of 12.7% for the boraxed treatment at 14 weeks, compared with 34.7% for non-boraxed fruit at 13 weeks.

(*Citrus News, 20: 143, Hrt. Abstracts, 16, 137, 1946*).

* * *

Use of 2, 4-Dichloro-phenoxyacetic Acid as a Selective Herbicide in the Tropics

Trials were made in Puerto Rico with 2, 4—D converted into the more water-soluble ammonium salt by the addition of NH 4 OH on an equimolecular basis. Major weeds in sugar cane and coffee plantations were killed, but neither cane nor coffee plants showed adverse effects with sprays up to 0.3%. The effect of 2, 4—D is to kill the growing point in a few weeks. It is sprayed on the weeds, but some comes into contact with the soil and it was detectable in soil 3-5 weeks after application. Radish seeds germinated in cotton soaked in 2, 4—D, and others grown in soil sprayed with 2, 4—D showed reduced root and shoot growth. Mature weeds, grasses and some other plants were relatively insensitive to 2, 4—D. (*Soils and Fertilizers*, 9, 213, 1946.)

THE DETERIORATION OF CANE AFTER BURNING FOR REAPING WITH SPECIAL REFERENCE TO BRITISH GUIANA

BY

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It is the general practice in British Guiana and elsewhere to burn the cane prior to reaping. This practice serves two purposes. Firstly, adhering trash (which makes manual cutting difficult) is burned away, and secondly the fire destroys considerable numbers of various pests that inhabit the fields. If the practice could be avoided, however, a certain amount of organic matter would be saved for incorporation in the soil and some deterioration of cane would be avoided since it not infrequently happens that after a field has been burned for reaping, this operation is delayed owing to rain or other causes.

The degree of damage to the cane cells as a result of burning, depends upon the temperature of the fire and this may vary greatly.

The deterioration of cane has received considerable study from time to time in various cane-growing areas. This is only natural since cane is very perishable material and considerable loss can result from delay in milling. It is the object of this paper to discuss this aspect in so far as it applies to British Guiana as the monetary saving by ensuring a supply of fresh cane to the factory is very considerable. The subject is also of interest in view of the importance of insuring cane against loss by malicious burning, strikes, etc.

A study of the literature in cane deterioration reveals a number of conflicting findings and views. For instance, in Louisiana, Browne and Blouin (1) found that when the tops are removed from cut cane, the rate of deterioration was less than if the tops were allowed to remain. On the other hand, Alvarez (2) found in Tucuman that the rate of deterioration of topped and untopped cane was the same. Again, Haldane (3) reported that under the same conditions, varieties shewing the greater loss of water shew the greater rate of deterioration. However, neither the early experiments of Cross and Harris (4) nor the more recent ones of Balch and Lauritzen (5) support this view.

It is perhaps not surprising that such differences should be found in view of the great variations in conditions under which experimental work has been conducted. On the other hand, there are many points of agreement. Thus, it has been demonstrated quite clearly that the rate of deterioration is a varietal characteristic and that storage and climatic conditions (particularly temperature) are also important factors.

Balch and Lauritzen, studying the deterioration of cane stored in factory yards in Louisiana, obtained definite indications that the rate of deterioration was reduced very appreciably by sprinkling water over the piles of stored cane. Cross (6) investigated the effect of submerging cane in water and reported that this reduced the rate of deterioration.

The effect of various field practices on the rate of deterioration of cane has been studied in British Guiana by Williams, Hugh and Singh (7). In these experiments, comparable and contiguous beds of the same cane variety were treated as follows :—

(a) Cane topped, harvested and milled daily i.e. supplying data for fresh cane.

(b) Topped one day, left standing and samples milled daily over a number of days.

(c) Burned and left standing, a sample being milled daily.

(d) Cane burned, cut, bundled and left exposed on the field.

(e) As (d) but bundles watered hourly from 7 a.m. to 4 p.m. daily.

The rate of deterioration was found to be greatest in the case of cane burned and left standing, and least where the cane was topped and left standing.

Rosenfeld (8) also discusses measures that may be taken by farmers to reduce cane deterioration in cases where due to force majeure, a planter may be forced to deliver cane to the factory some considerable time after it has been reaped. He advocates sprinkling of the cane and covering it with trash to keep it cool.

While the experimental work described in the literature has yielded valuable information, such work frequently suffers from three disadvantages. Firstly, the experiments are usually conducted on a small scale; secondly they are usually limited to one season, or a particular part of a season; and thirdly, the results are not usually presented in a manner which permits of ready valuation.

At Blairmont Estate, the cane from the various fields is milled and analysed separately and it is possible to obtain data on a large scale and which are applicable throughout the various crop seasons. The results of a study of this data for the period 1941 to 1946 are presented herein.

Loss of Weight of Cane

Loss in weight of cane can hardly be regarded as deterioration in the strictly chemical sense since there need not necessarily be a high degree of correlation between loss in weight and loss of sucrose. However, where cane is sold on the basis of weight, loss in weight represents deterioration in value to the vendor.

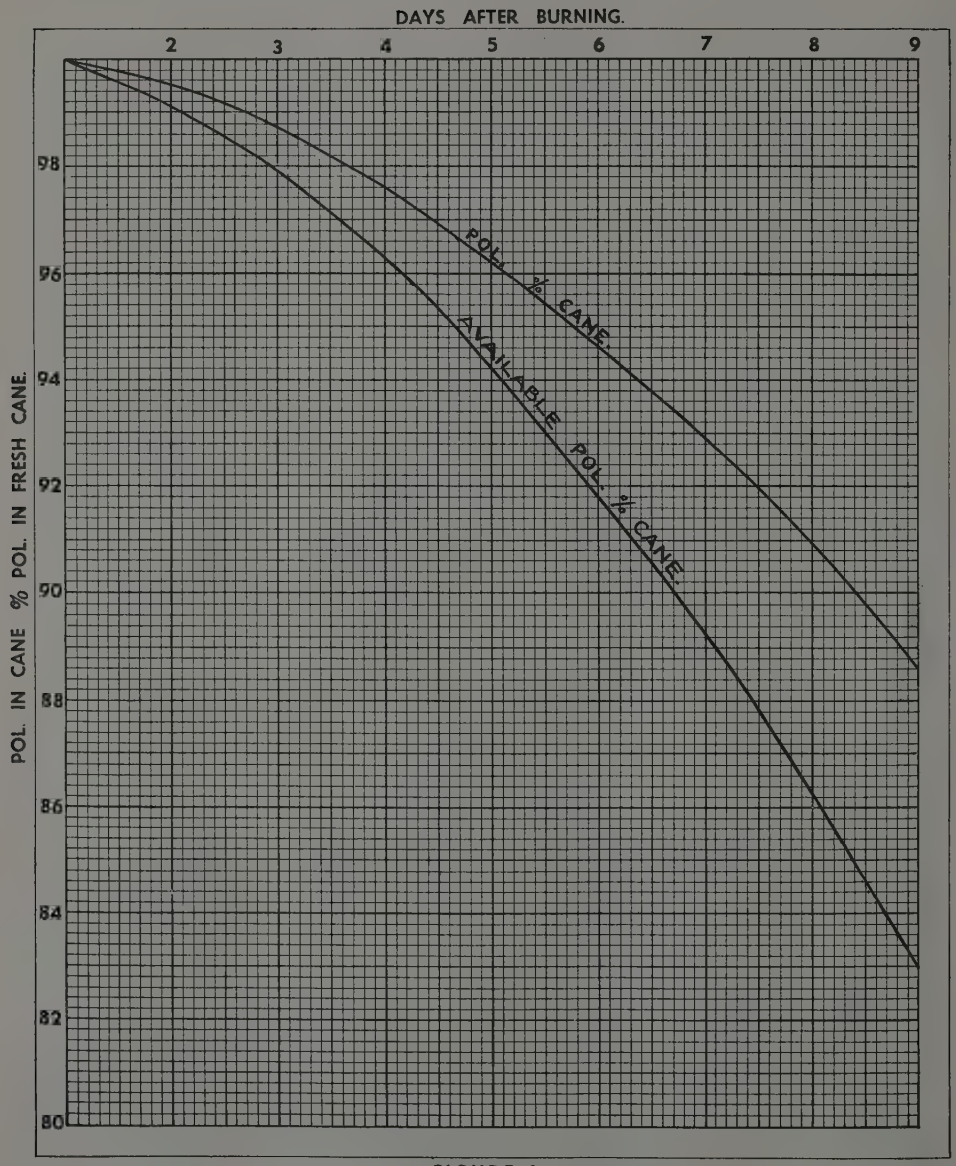
DAYS AFTER BURNING.
2
3
4
5
6
7
8
9
POL. IN CANE % POL. IN FRESH CANE.
98
96
94
92
90
88
86
84
82
80
POL. % CANE.
AVAILABLE POL. % CANE.

FIGURE 1.

At Blairmont Estate, the daily loss in weight of cane over a lengthy period is generally reasonably constant, although, as may be expected, any change in climatic conditions (temperature and humidity), as well as variation in storage conditions, may cause changes in rate. If the data from many tests be plotted, however, the relationship between loss of weight and period of storage is approximately linear. For the cane varieties Diamond 10 and P.O.J. 2878 at Blairmont Estate, the average loss in weight of cane per day is 1.11%.

Loss of Pol. % Cane and of Available Pol. % Cane

The rate of loss of Pol. % Cane and of Available Pol. % Cane is not constant but increases as the time between burning and milling increases.

The most useful method of presenting the data on loss of Pol. % Cane is by the use of indices which express the pol. in cane at time of milling, as a percentage of that of the fresh cane. In the case of the data obtained by the writer, that of cane one day after burning is taken as being fresh cane since data for the quality of the cane at time of burning are not obtainable.

Balch and Lauritzen (5) have claimed that on storage of cane there is a tendency for the Brix (total solids) to decrease. These losses are attributed to respiration. While such changes do occur, they are generally very small and may be neglected especially as inversion results in a slight increase in solids. It can therefore be assumed for practical purposes that there is no loss of solids but only of pol. If, therefore, the apparent purity of the juice from the cane one day after burning (fresh cane) be taken as 100 and that of the juice on subsequent days be expressed as a percentage of that purity, the figure so obtained will denote the pol. content of the cane at time of milling as a percentage of the original content assuming the cane from any one field was originally of uniform quality. While this assumption may not be strictly true for any given field, it is probably true in the aggregate.

Using the method just described, the data obtained are presented in Table I.

Table I

POL. IN CANE AS A PERCENTAGE OF THE POL. CONTENT IN FRESH CANE *i.e.* ONE DAY AFTER BURNING

Crop	Period	Days after Burning								
		2	3	4	5	6	7	8	9	10
1941	Spring	99.66	98.57	97.55	95.78	94.94	—	—	—	—
	Autumn ...	99.51	98.22	97.91	95.44	93.54	—	—	—	—
1942	Spring	99.60	98.40	97.53	94.91	92.65	92.03	—	—	—
	Autumn ...	99.69	98.21	96.35	94.90	93.73	93.35	91.18	91.90	—
1943	Spring	99.62	98.91	97.53	96.84	95.00	93.99	93.19	—	89.48
	Autumn ...	99.60	98.81	97.65	96.98	95.47	90.75	89.09	87.49	84.19
1944	Spring	99.63	98.87	98.23	96.35	94.77	93.34	90.71	88.15	—
	Autumn ...	99.58	98.45	97.08	95.15	94.65	91.06	88.40	86.50	85.87
1945	Spring	99.62	98.35	97.58	95.81	94.32	92.17	93.74	88.74	—
	Autumn ...	99.60	98.70	97.87	96.56	95.28	93.37	93.65	91.96	—
1946	Spring	99.68	98.80	97.80	96.33	95.54	93.74	91.52	86.00	—
	Autumn ...	99.65	97.84	96.41	95.52	93.89	91.51	89.32	88.27	—
	Means	99.62	98.51	97.47	95.88	94.48	92.53	91.20	88.63	86.51
Mean Loss of Pol. % Cane... ...		.38	1.49	2.53	4.12	5.52	7.47	8.80	11.37	13.49

The mean data are plotted in Fig. I along with the indices for the Available Pol. over the same period. These latter indices will be the same as those for the commercial sugar provided the mill and boiling house efficiencies are assumed to be constant as well as the composition of the commercial sugar. In actual practice, boiling house efficiencies are frequently decreased when processing juices from deteriorated cane and some allowance should be made for this. The allowance to be made, however, depends on many variables and this aspect has not been considered here in order to present the data as simply as possible.

The mean indices for the Available Pol. over the same period are shown in Table II.

Table II.

AVAILABLE POL. IN CANE AS A PERCENTAGE OF AVAILABLE POL. ONE DAY AFTER BURNING

	Days after Burning								
	2	3	4	5	6	7	8	9	10
Means	99.45	97.80	96.16	93.69	91.49	88.56	86.46	83.07	79.23
Mean Loss of Avail. Pol. % Avail. Pol. in Fresh Cane ...	.55	2.20	3.84	6.31	8.51	11.44	13.54	16.93	20.77

It will be observed that the loss of available pol. (and hence of commercial sugar) expressed as a percentage of the available pol. in fresh cane, is appreciably greater than is the loss at pol. by inversion. This is to be expected, since coincident with loss of pol. by inversion there is a decrease in juice purity and such pol. as remains is less available by virtue of this decrease in the purity of the juice. Thus, (from Table I) 6 days after burning, the mean loss is 5.52% of the pol. originally present. On the other hand, for the same time interval between burning and milling, the loss of available pol., and hence of commercial sugar, is 8.51% (Table II).

The grinding of cane more than 6 days after burning is largely the result of poor labour conditions during and following the war. At Blairmont Estate, the cane is usually burned at night and cutting commences the following day. The reaping of a field may last 3 or 4 days or more depending on the labour supply, the weather, the stand of cane and the number of punts supplied to the section. When labour is scarce and the crop has extended into the rainy season, or, if there has been a factory or transportation breakdown, cane may be milled as late as 7 to 10 days after burning. The loss of *sugar* will average from 12 to 20% in such cases. Usually, however, the greater part of the cane is milled 3 to 5 days after burning.

The data presented in Table I represent mean results for the various crops and therefore the variations caused by climatic conditions and cane variety are not evident. These two factors require brief consideration.

Cane Variety

Between 1941 and 1944, the cane supply consisted almost entirely of the varieties P.O.J. 2878 and Diamond 10. During 1945 and 1946, appreciable quantities of Co. 421 and Co. 419 were also reaped. The mean data for the three chief varieties are tabulated in Table III.

From Table III, it will be noted that Diamond 10 deteriorates less rapidly than P.O.J. 2878, and Co. 421 somewhat more rapidly.

Climatic Conditions

The rate of deterioration of cut burnt cane is less rapid in rainy weather than in dry. A comparison of the indices for September (a dry month) and December (a rainy month) will serve to illustrate the differences which arise from varying climatic conditions (Table IV).

Table III

Cane Variety	Index — Days after Burning									
	1	2	3	4	5	6	7	8	9	10
Diamond 10	100.00	99.81	98.69	98.01	96.58	94.94	93.74	92.70	89.89	—
P. O. J. 2878	100.00	99.37	98.54	97.36	95.64	93.95	91.94	89.53	87.56	86.63
CO. 421	100.00	99.18	98.19	96.81	95.84	93.64	91.98	88.96	—	—

Table IV

Month	Index — Days after Burning									
	1	2	3	4	5	6	7	8	9	10
September	100.00	99.31	98.35	97.22	95.84	94.11	92.30	—	—	—
December	100.00	99.80	99.03	97.91	97.17	95.56	93.76	92.73	90.81	88.88

Reference to Table I clearly indicates that the loss of pol. owing to delay in getting cane to the mill after its burning can be very considerable, the loss over any given time interval increasing rapidly as time elapses. A factory superintendent would be extremely pleased to increase the recovery of pol. in the factory by 1 or 1½%, and considerable capital outlay to obtain such increases would be justified, yet, as may be seen from the data above, many times this amount may be lost in failure to get cane to the mill with the minimum of delay. There is little doubt that in many cases better organisation of reaping programmes would pay handsome dividends in the recovery of sugar now lost owing to failure to realise the costliness of such delays.

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Problem of New Coffee Plantations in Worn-out Red Soils

The acid, reddish-purple (terras roxas legitimas) soils of Sao Paulo are highly laterized and after losing their virgin content of humus under open-culture conditions (suppression of weeds) become very infertile. Phosphate is immobilized in the soil except when copious and prolonged rains carry it to the roots of the trees before calcium and aluminium oxides can combine with it. Potash is quickly leached out owing to the absence of zeolitic soil minerals. Due to the absence of organic matter there is practically no soil microflora and hence no available reserves of soil nitrogen. Lime alone produces a slight effect when added in very large amounts. Pot experiments indicate that the sole means of restoring these soils to coffee production is an abundant supply of organic matter; the resulting organic soil colloids retain potash, solubilize phosphate, and together with lime provide a base for a more or less normal supply of soil nitrate. (*Chemical Abstracts*, 40, p. 5520, 1946.)

* * *

A New Tomato for the Tropics

The outstanding feature of the new tomato variety Turrialba, produced at the Inter-American Institute of Agricultural Sciences, Costa Rica, and described in *Agric. Amer.* 5, p.233, is that it is suitable for growing under lowland tropical conditions. It is a cross of the temperate high-quality variety Cuban Marglobe and of a cherry-like wild type, a compound-ovary, lace-leaved selection of *Lycopersicum esculentum* var. *cerasiforme*. The fruit averages 3-3½ inches in diameter. It is firm-fleshed and bright red throughout and has a moderately smooth, blemish-free skin. Flavour and appearance are suggestive of Marglobe. Resistance to diseases, including *Alternaria solani*, appears to be satisfactory. It is however, not yet ready for general distribution. (*Hort. Abst.* 16, 136.)

Influences of Certain Mineral Substances on the Quality of Sugar Cane

The effects of different rations of calcium, magnesium, and sodium when associated with different rations of nitrogen and potash in the nutrients supplied to sugar cane have been recorded in experiments recently carried out in Hawaii. The results are difficult to interpret correctly since the replicates did not always react alike to the known treatment applied, and some canes actually died. In such cases the specific effects of the mineral combination involved are probably masked.

The principal effects have come from the nitrogen-potash ratios. Not many clean-cut influences from the different calcium-magnesium and nitrate ratios or interactions between these two ratio groups were established.

The highest yield of total dry weight, of millable cane, and of sugar were generally secured from the high nitrogen-high potash series, whereas most of the lower yields came from the high nitrogen-low potash series. The best juice purities and yield per cent. cane were found in the low nitrogen-high potash series. Thus high potash stands out as being especially important in connection with both cane quality and yields.

A complementary effect in the absorption of nitrogen and potash by sugar cane is seen in the facts that (a) when the same amount of nitrogen was applied, the per cent. nitrogen in juice and in leaf-punch samples was higher when the potash supply was low; and (b) when the same amount of potash was supplied, the per cent. potash in the juice was definitely higher when the nitrogen supply was low.

The calcium-magnesium-nitrate effects suggest an influence on the per cent. nitrogen and potash in the juice. The ½—2—1 ratio produced cane with a high concentration of nitrogen and a low concentration of potash in juice. The ratios with high magnesium seem to have depressed the uptake of potash.

DIFFICULTIES IN MANGOSTEEN CULTURE

By

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Introduction

The fruit of the mangosteen, *Garcinia mangostana* L., has been extolled by practically everyone who has written on the subject. It has been likened to a number of better known fruits but everyone admits that it has its own delicate indescribable flavour. It excites the appetite and fortunately can be eaten in large quantities without harm. Its flavour is destroyed in canning but an agreeable preserve can be made by boiling with sugar (3, 30). The inclusion of the seeds adds a nutty flavour.

Fairchild reports (13) that the seeds are edible when cooked. The rind is valuable as an excellent tanning agent, and has proven useful when sliced and dried as a remedy for dysentery, chronic diarrhoea, and cystitis (9). The heavy, dark brown, durable wood barely floats in water (29). It is useful in woodwork and building construction but limited by relatively small dimensions.

It is evident that the mangosteen is a valuable plant which should by now be well established in the Western Hemisphere. However, with the exception of the United Fruit Company which has 9 acres of bearing trees and 19 additional acres of small trees, in Honduras, no systematic plantings have been made in recent years to the writer's knowledge.

In this discussion we will consider the conditions under which the mangosteen grows, and the reasons why this crop has not been better established, based on the literature and on observations and experiments conducted at the Federal Experiment Station, Mayaguez, Puerto Rico.

Physical and Geographical Requirements

The mangosteen tree is of medium size. Various authors give the range in height from 20 ft. to 45 feet. Its shape is described by Gregson (16) as pyramidal. The trees at Mayaguez are irregularly columnar with a hemispherical top. The leaves are 6 to 10 inches long and glaborous on both sides with a prominent mid-vein.

The terminal bud is hidden in cavities within the base of the petioles of the last pair of leaves except when actively elongating. Flowers are solitary, terminal, 2 inches in diameter and rose coloured. Ridley (20) describes the tree as a fairly rapid grower but Gregson (16) and others, including workers at this station, consider it a slow grower, particularly in the early stages.

There is a high degree of uniformity among the trees of a given orchard, far more than could be expected on the basis of experience with seedlings of other types of fruit. However, there have been several varieties described including a particularly late variety in Burma (16) and a more acid one in Java. The location has considerable effect on the quality of the fruit (27), and altitude as well as latitude affect the time of flowering and fruiting (27).

The mangosteen originated in the East Indies although its natural range has not been well defined. Cultivation is now established throughout the East Indies, Southern Philippines, Burma, Malaya, Cochin China, Siam, South Eastern India, and Ceylon. Occasional trees as well as a few orchards are found in the West Indies and continental tropical America (27). The many attempts to establish plantings in a cooler climate such as the northern Philippines, China, Australia, and Florida have generally failed (27, 32). It is confined to lower elevations with 1,500 feet being about the maximum. Superior growth is obtained near sea level.

A high well-distributed rainfall appears necessary for successful culture. Even in Burma where precipitation reaches 200 inches, irrigation is necessary for good crops during the dry season (16). On the island of Dominica, B.W.I., mangosteens receiving 80 inches a year required great care to grow at all but thrived at another location with 105 inches in a more retentive soil (27). Several authors have pointed out the superiority of plants growing under irrigation. A soil in which the water table is maintained within 6 feet of the surface is considered very desirable (15, 16, 23, 26). The importance of this condition is evidenced by the successful growth of mangosteens in close proximity to streams, lakes, or other bodies of fresh water.

Drainage is necessary, particularly with young plants, although Higgins (18) describes the Canal Zone plantings as on soil too wet for other fruit tree crops during the entire rainy season, and Fairchild (12, 13) describes an orchard in a swamp, with full drainage ditches between the rows and another where the orchard was almost constantly under fresh running water. Most of the failures with mangosteen plantings in Puerto Rico probably can be attributed either to an excess or deficiency of water; the latter frequently occurring during the 3 to 6-month dry season.

The trees grow well in clay or sandy loam; the chief soil requirement appears to be a high organic matter content.

Some wind protection is highly desirable for a mangosteen planting. Hot moist valleys or other protection from drying winds or gales is necessary for good production. In Jamaica the trees were found intolerant of the sea breezes (27) which presumably carried salt.

Mangosteen Culture

Seed. Early distribution of the mangosteen throughout its geographically adapted range apparently was prevented because of the short viability of the seed. If the seed are left in the fruit they retain viability for 3 to 5 weeks but when removed they last only a few days unless protected against drying. According to Lindsay (23) and Oliver (25) the best method to ship seed is in sealed cans containing very slightly damped charcoal. It is obvious that seed should be planted as soon as possible. Hart (17) in Trinidad records much better growth from seed obtained from Singapore than with locally-grown seed. At Mayaguez, superior plants have been obtained in recent years from seed secured from the Canal Zone over those locally produced. Both Malasia and the Canal Zone appear somewhat better suited for mangosteen culture than most islands of the West Indies.

Seed germination and seedling development. The work of Sprecher (31) on the nature of the mangosteen seed has shown that it is not a true seed in a botanical sense but a hypocotyl-tubercle, or, a primitive adventitious embryo originating from a cell of the ovary inner wall; it is simply a tuberous stem from which the new plant develops. It is never fertilised and thus represents a special form of vegetative reproduction. Horn (21) has shown that the striking uniformity among mangosteen trees is the result of this asexual propagation. Germination begins with the development of two swellings at opposite sides of the "seed"; the first root arises from one swelling while the shoot develops from the other. Later a new root system develops from the base of the shoot and the original root system usually ceases to function. Hume and Cobin (22) have shown that better germination, survival, and subsequent early growth can be obtained from large seeds. The use of seeds weighing over 1 gram is recommended.

The media for germinating should be high in organic matter, but well drained. Oliver (25) recommends a mixture of leaf-mold, sand and charcoal, and Parsons (26) suggests a rich soil with ample leaf mold, while Gregson (16) recommends 5 parts top soil and 3 parts burnt soil. The method of handling is quite variable. In the plantation at Tela, Honduras and also at the Canal Zone Experiment Gardens the seeds are germinated in pots and transplanted at the 2-leaf stage to deeply prepared nurserybeds supplied with plenty of organic matter. Plants are spaced 12 to 15 inches until they are 2 feet high, when they are transplanted to a permanent location. In Burma a recommended alternative is to plant the seed in pots 1 to 1½ feet deep where they remain until ready for planting in the orchard. Both methods overcome to a great extent one of the most serious cultural problems during the early growth period. At this stage seedlings often cease growing, turn yellow, and the leaves develop dead areas. Plants in this condition rarely, if ever, recover. The mangosteen tap root is very long, delicate, and easily damaged by contact with the bottom of a pot with a consequent serious checking of growth. Furthermore, the lateral roots of a seedling are normally formed at a depth considerably below the bottom of the usual sized pot. At Tela, Honduras the majority of lateral roots were found at a depth of 4 to 10 inches (27). This deep-rooted nature of the plant also presents difficulty at the time of transplanting. The trouble is so serious that Hart (17) recommends direct seeding in the permanent location and most authors recommend permanent planting before the plants exceed 2 feet in height. At this stage the root system may be deeper than the top is tall. Plants from nurserybeds must be moved with a deep ball of earth; and those growing in bamboo pots should have the pots split carefully to avoid root damage.

Efforts to overcome early death and slow growth in seedling stage. Horn (20) has shown that early growth can be stimulated by frequently supplying an extract of Brewer's yeast.

Many efforts have been made to overcome the weak root system of the young plants. Propagation by cuttings has been reported (1) as follows: "Increase is effected by ripened cuttings which root readily in sand under a hand glass in heat." Evans (10) also reports that cuttings have been tried in Trinidad with a fair degree of success. This method appears to be the most practical if a high percentage can be rooted. Budding is reported by Fielden (14) as successful if the two horizontal cuts are made 6 days earlier to avoid fermentation. Grafting can be accomplished insofar as union of the stock and scion is concerned but the later results have generally been unsuccessful. Oliver (25) succeeded in uniting mangosteen scions on 20 other *Garcinia* stocks by inarching on mature mangosteen trees. The new plant is formed by gradually cutting below the union on the mangosteen and removing the top of the stock. All of these grafts, as well as those on species of *Calophyllum and Platonia* were not satisfactory because of incompatibility or different growth rates. In several instances the scions developed roots and established themselves but the stocks eventually died. A more successful method was to establish a mangosteen seedling in the same pot with a *G. tinctoria* plant and inarch them (25). Unhealthy seedlings were revitalised and made better growth on their own roots as a result of contact with the nurse plant.

Considerable time and effort has been expended all over the tropical world to find a suitable stock for the mangosteen. Wester (34) claims the Bumag, an unidentified *Garcinia,* which is a native of the Sulu Archipelago and southern Philippine Islands, has served as a successful stock for at least 5 years. He reports it to be a vigorous grower and capable of resisting considerable drought. He also recommended trying other species of *Garcinia* with terminal inflorescence and especially with a hard pericarp which would be closely related and consequently more likely to be compatible. Macknight (24) recommends propagation from suckers or basal sprouts.

Water relations. Water supply appears to be extremely important, particularly in the early stages of development. The root system in addition to being notoriously weak is devoid of root hairs both in seedling and mature state as observed at Mayaguez. Plants with root hairs have an advantage because their roots are in contact with a much larger volume of soil from which to obtain water. At Mayaguez, especially built nurserybeds with moderate shade (400 to 1,800 foot-candles) apparently failed to develop healthy plants because of inadequate water supply during the dry season. On the other hand, the young plants need good drainage. In the seedling stages standing water over the roots kills them quickly. At Mayaguez, plants in forest nurserybeds with about as much shade as nearby vigorous plants were receiving, but where adequate drainage was not provided, were dead within a year after planting.

Shade. There is some question as to how long or how much shade is necessary for the young plants. In the Canal Zone (18) a light shade for seedling plants and nurserybeds was adequate while Ulbricht (32) states that heavy shade is necessary in the nurserybeds. The orchard area he believes should be preplanted to shade trees which can be thinned out gradually. It appears that some shading at least is beneficial during the first 4 to 5 years. At Mayaguez, plants in nurserybeds with insufficient shade, where the leaves were exposed to direct sun (generally 8,000 to 12,000 foot-candles) for an hour or more daily, have been completely eliminated while those under dense shade (80 to 400 ft.-c.) have made very little growth. A partial, but evenly distributed shade, except on the north side, has given the best results in the nurserybeds. Satisfactory growth of mangosteen seedlings was obtained in plots receiving 400 to 1,300 ft.-c. on an "average" day.

Fertilisation. The occasional application of liquid manure to seedlings is beneficial according to Gregson (16). In a single experiment at Mayaguez neither manure mixed with a peat substrate nor a 6-8-9 chemical fertiliser mixed with the substrate, nor on the surface 6 months later gave beneficial results. Dilute organic fertilisers which can be absorbed slowly are perhaps desirable, but the mangosteen is apparently not capable of utilizing strong concentrations of nutrients. Soils with high organic matter content are apparently beneficial as a source of nutrients.

Orchard Problems

Time of bearing. The mangosteen comes into bearing relatively slowly. The shortest time recorded is 8 to 9 years from planting in Ceylon (26), and other authors report from 10 to 20 years. The two oldest trees at Mayaguez required 20 years to produce the first fruits. Bearing is irregular, occasionally a light second crop is obtained in the same year, but once in a while an entire year is skipped. Vigorous bearing trees may yield 500 to 1,500 fruits most years for many years. Growers are hesitant to plant mangosteen orchards because of the long time required before there can be any possible returns on their investment. This difficulty can partially be alleviated by intercropping with shorter cycle crops as pineapple, arrow-root, ginger, and pepper. They not only help defray the cost of establishing the orchard but also supply tillage and fertilizers for the mangosteen trees.

Mulching. In Ceylon, Parsons (26) reported that the trees are mulched with leaves or coconut husks during the dry season. Although this subject is not given much consideration in the literature, it would seem particularly desirable in any locality having a well-defined dry season.

In this connection some information supplied by David G. White about mangosteen culture at the Firestone Plantations in Liberia is of particular interest. The usual 3-month dry season necessitated frequent watering for 10 years to prevent the tops from drying. However, in another equally dry season when a 16-inch grass mulch was applied as the rains were ending, the plants continued in good condition without irrigation. The mulch was applied from within a foot or 2 of the trunk to 2 feet beyond the spread of the branches.

Pruning. Little or no pruning is practised commercially. The only pruning recommended is the removal of the dead and diseased wood, the upright growing suckers, and any excessive weak, interior branches.

Predators and Diseases. There are several animals, insects, and diseases reported attacking mangosteen. None is very serious except those affecting the fruit. In Puerto Rico the chief difficulties are coffee thread blight, *Pellicularia* (*Corticium*) *koleroga* Cooke (4), bats (28), and rats.

Harvesting. Harvesting in the older established areas is accomplished chiefly by cutting the stem with a knife attached to a long stick. Hand picking from ladders or orange clippers would be much more desirable, especially for shipment, since the pericarp at that stage is still slightly soft and subject to injury from falling.

Shipping

Long distance shipments have been made successfully. Campus (6) reported fruit shipped from Cochin China to Paris after surface disinfection, and Fairchild received fruit in perfect condition after 3 weeks transit from Trinidad to Florida (11). Shipments from Burma to London were discontinued for a time because of the high percentage of rot developing during transit. Earliest shipments from Honduras to New York were also a failure for the same reason. Spraying with Bordeaux in the orchard has been recommended to reduce the amount of infection prior to harvest. Surface disinfection prior to packing also has been suggested. Dipping in latex or other protective coating has proved slightly beneficial (16). With reduction in air freight rates shipping difficulties should be minimised. Mangosteens do not ripen appreciably in transit so that they cannot be picked until "almost ripe."

Ripening is indicated by a hardening and darkening of the pericarp. Fruit should be picked before it becomes difficult to dent as determined by overall pressure with the fingers when placed in the palm of the hand.

The United Fruit Co. has made numerous small shipments to the United States during the past year with good success. The fruit were packed in small crates similar in size to a tomato lug and shipped at 52 deg. to 56 deg. F. The outer husk was still relatively soft after 20 days. Hardening of the husks in previous shipments had apparently resulted from drying or bruising with the development of what appeared to be *Diplodia* rot. Individual wrapping of the fruits in paper did not result in superior condition on arrival.

Conclusions

1. The mangosteen will apparently grow best in tropical climates where the temperature is continually warm, the elevation low, and where there is adequate wind protection and plenty but not excessive amounts of water either from irrigation or evenly distributed rainfall. The soil should be high in organic matter.

2. There is very little variation among trees in the orchard because the so-called seed contains an asexually produced adventitious embryo.

3. The seed remains viable for a very short time unless especially packed to prevent drying.

4. High seedling loss is encountered if the root system is confined. Plants so checked in growth seldom recover and develop satisfactorily.

5. Small seeds have lower percentage germination and survival and make less growth in the early stages than heavier seeds.

6. Grafting to overcome the difficulties involved with weak seedling root systems has generally failed because of incompatibility of the stocks tried. The Bumag, a Philippine *Garcinia,* has shown promise.

7. Seedlings in early stages of growth should be watched carefully and never permitted to dry or become waterlogged or exposed without shade. The lack of root hairs is believed to be chiefly responsible for difficulties in water absorption by the roots.

8. The trees do not begin to bear until 8 to 20 years old. They yield a good but uneven crop of 500 or more fruits per tree in most seasons for many years. Intercropping with other crops is recommended for carrying the early cost of maintenance.

9. The fruit should be carefully picked to avoid damage, especially for shipping. Long distance shipments involving many weeks have been made but are sometimes accompanied by failure due to the fruit rotting in transit. Orchard spraying previous to harvest and surface disinfection of fruits before shipment have been recommended. Air express may help solve many shipping difficulties.

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CHEMICAL NOTES

(Compiled by the College Department of Chemistry and Soil Science)

New Weed-Killing Spray in Hawaii

The use of Diesel oil as a weed-killing spray has been well known, but as commonly used large volumes are required. By a process patented by the HSPA (U.S. Patent No. 2,370,349) the oil can be activated to such an extent that instead of 25% of Diesel oil in a common emulsion, only 2.8% of the new emulsion is needed for treating succulent weed growth. This emulsion in a concentrated and highly activated form has now been developed to the point where it can be prepared at a central plant and transported to the field, where one part of the concentrate may be diluted with 30 parts of water to make the finished spray. This is very convenient for irrigated plantations, where the water can be taken from a ditch instead of being hauled to the field; 250 gallons of concentrate are sufficient for a full day's operation of a gang using portable sprays. Where weeds and grasses have been growing for some time the dilution of the concentrate may be 1 to 24, and in special cases of very heavy and hardy grass growth the dilution may be lowered to 1 to 12. The fieldmen report that this system of weed control is superior to any other chemical herbicide that has been tried in the past. The cost of materials employed is actually less than for commonly used herbicides. This Diesel emulsion is non-poisonous and leaves no permanent residue in the soil; it is non-irritating to persons who handle it, and is not unduly destructive when accidentally applied to sugar cane. —(*SUGAR*, 42,52, 1947.)

Shaping the Future of Hawaii's Agriculture

1. The tissues of the *sugar cane* plant which serve best as index tissues for adequacy of water, potash, phosphate, calcium, magnesium, nitrogen, and total sugar nutrition have been selected after six years of research.

2. *Coffee plants* were grown in water culture under three different sunlight intensities to determine the effect of sunlight on nitrate utilization by the plants. Shading resulted in increases in the content of total, soluble, insoluble, ammonia, amide, nitrate, a-amino, and peptide nitrogen, and hemicellulose. Shading also resulted in a decrease in dry matter, soluble sugars, and starch. Potash, calcium, and phosphate increased with shading.

3. Severe potash deficiency resulted in an increase in the soluble nitrogen content of the leaves. Severe phosphate deficiency resulted in abnormal increases in total, soluble, ammonia, amide, nitrate, basic, a-amino, and peptide nitrogen.

4. Nitrogen proved to be the only element of fertilizers producing a positive effect on Napier grass.

5. Yields of Kola Haole (*Leucaena glauca*) were also increased with the addition of nitrogen.

6. Deficiency of boron resulted in the appearance of brown necrotic areas between the veins in the central and basal regions of blades of young, partly expanded leaves of the *coffee plant;* mature leaves were not visibly affected.

7. Plants suffering from insufficient manganese become uniformly light yellow-green in colour at first but later chlorotic areas developed.

8. The young leaves of plants grown without copper showed tiny chlorotic spots throughout the blade.

9. Studies of non-exchangeable potash removed from the soil by Napier grass even when potash was not included in the fertilizer suggest that existing concepts of potash availability in certain Hawaiian soils may require revision. Determinations were made of the potash content of several Hawaiian soils to 54 inches below the surface.

10. The soil colloids of Hawaiian soils were investigated. It is suggested that high base-exchange capacities are the result of large amounts of iron silicates. Colloids from soils formed under low rainfall are predominantly kaolinitic. In soils formed under heavy rainfall, the colloids are largely limonitic; some are believed to contain a titaniferous mineral. Colloids formed under anaerobic conditions were free of ferric oxides.

11. The utilization of Kao Haole (*Leucaena glauca*) as a forage legume is hindered in part by its toxic principle mimosine, present in the dry leaves and seeds to the extent of 3.5%; when fed to rats, its toxic effects were overcome if sodium ferric phyrophosphate was simultaneously fed. The colour reaction of mimosine with ferric chloride can be used as the basis for a spectrophotometric method of quantitative analysis. (*Chemical Abstracts*, 40, 18, p. 5513, 1946.)